LIST OF THE OFFICERS

OF

The Institution of Petroleum Technologists, 1933-1934

Past-Presidents:

*Sir Boverton Redwood, Bart., D.Sc., F.R.S.E. (1914-1916).
Prof. Sir John Cadman, G.C.M.G., D.Sc., M.Inst.C.E., M.Inst.M.M. (1916-
The Rt. Hon. Lord Greenway of Stanbridge Earls (1917-1919). [1917).
*Sir Frederick W. Black, K.C.B., B.A. (Lond.) (1919-1921).
Prof. John Samuel Strafford Brame, C.B.E., F.I.C., F.C.S. (1921-1923).
*Herbert Barringer, M.Inst.C.E., M.I.Mech.E., M.I.N.A., M.Inst.Mar.Eng. (1923-1925).
Sir Thomas H. Holland, K.C.S.I., K.C.I.E., D.Sc., F.R.S. (1925-1927).
Alfred C. Adams (1927-1929).
A. E. Dunstan, D.Sc., F.I.C., F.C.S. (1929-1931).
James Kewley, M.A., F.I.C., F.C.S. (1931-1933).

President:

T. Dewhurst, A.R.C.Sc., F.G.S.

Vice-Presidents:

Ashley Carter, A.M.I.Mech.E.
C. Dalley, M.I.E.E.
Alexander Duckham, F.C.S.
Arthur W. Eastlake, M.I.Min.E., A.M.I.Mech.E.
J. McConnell Sanders, F.I.C., F.C.S.
F. B. Thole, D.Sc., F.I.C., F.C.S.

Members of Council:

Lt.-Col. S. J. M. Auld, O.B.E., M.C., D.Sc.
Sir John T. Cargill, Bart., Hon. LL.D.
A. E. Chambers, A.M.Inst.C.E.
G. H. Coxon.
A. Frank Dabell, M.I.Mech.E.
B. J. Ellis.
Elliott A. Evans, F.C.S.
F. H. Garner, Ph.D., M.Sc., F.I.C.
T. R. H. Garrett, M.A., F.G.S.
John Gillespie, M.I.Mech.E.
Prof. V. C. Illing.
J. S. Jackson, B.Sc., A.I.C.
Prof. A. W. Nash, M.Sc., F.C.S., M.I.Mech.E.
James Romanes, F.G.S.
A. Beeby Thompson, O.B.E., M.I.Mech.E., M.Inst.M.M., F.G.S.
A. Wade, D.Sc., A.R.C.S., F.G.S., M.Inst.M.M., F.Am.G.S.

Honorary Treasurer: Lord Plender of Sundridge, G.B.E.
Solicitors: Messrs. Ashurst, Morris, Crisp & Co.
Auditors: Messrs. Price Waterhouse & Co.

* Deceased.

Bankers:
WESTMINSTER BANK, LIMITED,
21, Lombard Street, London, E.C. 3.

Hon. Editor:
A. E. DUNSTAN, D.Sc., F.I.C., F.C.S.

Hon. Librarian:
A. WADE, D.Sc., A.R.C.S., F.G.S., M.Inst.M.M., F.Am.G.S.

Associate Editor, Librarian and Secretary, Standardisation Committee:
GEORGE SELL.

Hon. Secretary:
ARTHUR W. EASTLAKE, M.I.Min.E., A.M.I.Mech.E.

Secretary:
Commander R. E. STOKES-REES, R.N.

Offices—Aldine House, Bedford Street, Strand, London, W.C.2.
Telegrams Instpetech, Lesquare, London.
Telephone: Temple Bar 1842.

CONTENTS.

	PAGE
Council Officers	i-ii
General Notices	v-vi
Personal Notes and Special Notices	vii-x
Reports on the Progress of Naphthology, 1932.	
Geology of Petroleum. By Prof. V. C. ILLING ..	427
Geophysics. By OSCAR WEISS	437
Field Technology. Edited by B. J. ELLIS	448
Refining. By W. J. WILSON, F.I.C., A.C.G.I. ..	497
The Cracking Art in 1932. By GUSTAV EGLOFF, Ph.D., M.A., M.Am.Inst.Chem.E., M.Am.Chem.Soc., and BADONA L. LEVINSON	504
Distillation and Fractionation Equipment. By Dr. R. K. FISCHER	529
Chemical and Physical Refining. By B. C. ALLIBONE, A.R.C.Sc., B.Sc., A.I.C.	539

ABSTRACTS.

PAGE

Class 100. Geographic Occurrence 205A
„ 200. Geology and Origin 210A
„ 300. Development and Production 210A
„ 400. Transportation, Storage and Distribution 217A
„ 500. Properties and Their Determination 219A
„ 600. Refining and Refineries 227A
„ 700. Utilisation 248A

AUTHOR INDEX.

The numbers refer to the Abstract Number.

Alden, R. C., 540
Alforov, B. A., 506
American Petroleum Institute, 573
Anderson, A., 531
André, E., 542
Andrews, O. E., 577
Anglo-Persian Oil Co., 531
Anthes, E., 591

Badgett, J. L., 531
Bailey, W. C., 531
Becker, W., 606
Behimer, O., 587
Bergman, D. J., 587
Birkhimer, E. R., 591
Bitner, F. G., 541
Blair, M. G., 540
Bolles, G. R., 596
Born, S., 568
Bost, R. W., 545
Bottom, W. G., 531
Bradford, B. W., 549
Bridgeman, O. C., 541, 554
British Thomson-Houston Co., 595
Browne, V. B., 587
Brunn, J. H., 548
Buchler, C. C., 563
Burn, W. S., 600

Carette, M., 538
Carter, R., 587
Chapman, C. M., 582
Cizancourt, H. de 504
Clark, E. M., 589
Clarkson, R. G., 571
Cockrell ,W. L., 583
Conn, M. W., 545
Cooper, W. O., 531
Coubrough, G. B., 592
Craig, E., 531
Crittis, W. J., 531

Darrow, M. S., 590
Davies, S. J., 598
Davis, B. H., 531.
Davis, L. L., 532
Davis, W. T., 596
Day, D. E., 590
Deisenhammer, E., 560
Denison, I. A., 533
Diggs, S. H., 563
Dreyfus, H., 587
Du Pont de Nemours & Co., 594
Dubbs, C. P., 587
Duff, R. L., 576

Egloff, G., 567, 587
Eurit, C., 531
Ewing, C. R., 591

Fain, J. M., 605
Fairchild, O. H., 587
Fletcher, H. W., 531
Foran, E. V., 514
Forward, C. B., 596
Foster, A. L., 574
Fuller, I. K., 591

Galish, F. A., 531
Giesey, R., 531
Giffen, E., 598
Gilliams, F. B., 519, 558
Gladden, S. C., 537
Gohr, E. J., 589
Goldsbrough, R. E., 588
Graybeal, J. W., 520
Green, J., 572
Green, J. R., 547
Greensfelder, B. S., 561
Guichard, P., 587

Haeck ,A., 593
Haley, K. W., 531
Halle, H. J., 587
Hammer, O., 531
Hampton, A. L., 531
Harcourt, G. M., 593
Hardman, C. M., 503
Harnsberger, A. E., 587
Hawthorn, D. G., 518
Hayes, A. H., 535
Heap, A. C., 607
Heinecke, G. E., 575
Henriksen, A., 591
Herthel, E. C., 587
Hicks-Brunn, M. M., 548
Higburg, W., 593
Hinrichs, C., 532
Hixson, A. W., 605
Holloway, J. H., 544
Howard, W. P., 587
Howes. D. A., 601

Hudnall, J. S., 525
Huff, L. C., 587

Illing, V. C., 512
Imperial Chemical Industries, Ltd., 594

Jasper, T. McI., 577

Kaffer, H., 589
Kallam, F. L., 596
Kelley, C. L., 606
Kimura, H., 595
Kirk, H. C., 587
Kirschbraun, L., 592
Knowlton, D. R., 531
Krauch, C., 589, 591
Krase, W. W., 544
Kuhl, P. E., 596
Kurty, S. S., 591

Laird, W. G., 587
Lander, C. H., 602
Larkin, J. L., 531
Larson, L. J., 577
Ledeen, H., 522
Lees, G. M., 511
Lembeke, H., 531
Lewis, J. O., 528
Loomis, A. E., 587
Louis, M., 538
Lunsford, R. C., 531

MacClatchie, J. W., 531
Marek, L. F., 546
Martin, W. M., 547
Matsunawa, —, 591
Maze, C. D., 531
McKee, S. A., 541
McLaughlin W. I., 531
McMonagle, J. A., 585
Meijer, R., 596
Mellor, J. F., 531
Miller, S. P., 557
Mills, B., 521
Minor, R. S., 531
Moor, H. H., 564
Morgan, R. A., 595
Morrell, J. C., 567, 590
Muller, B., 536
Murphy, G. B., 552
Musser, N. B., 534

National Supply Corporation, 531
Nelson, E. F., 587
Nelson, W. L., 556
Neuhaus, M., 546
Newell, H. B., 578
Nonawa, —, 591

Otis, H. C., 526

Page, J. M., 563
Parsons, C. P., 513
Perfilyev, M., 507
Pew, A. E., 591
Phillips Petroleum Co., 531
Pier, M., 589, 591
Pines, C. A., 585
Pippin, H. A., 531
Pokorny, O. S., 564
Pollock, R. T., 587
Porfiriev, V., 508
Powell, C. L., 531
Putnam, M., 516
Querfield, D., 554
Ragatz, E. G., 566
Ramage, A. S., 594
Reichel, F. H., 595
Rhodes, E. O., 588
Rice, H. B., 581
Ricker, L. H., 531
Rogers, F. H., 531
Rogers, T. H., 570
Rostin, H., 590

Sachanen, A., 550
Saunders, S. W., 559
Sawdon, W. A., 517, 524
Scheuman, W. W., 553
Schmidt, P., 531
Sclater, K. C., 527
Scott, E. D., 531
Scott, F. L., 531
Seamark, L. M. C., 531
Sellers, A. I., 565
Shaffer, W. D., 531
Shaw, S. F., 529
Sheldon, W., 531
Sinclair, D. A., 539
Sinclair Refining Co., N.Y., 591
Smith, F. F., 559
Smith, H. R., 531
Smith, S. S., 596
Smith, W. M., 531
Speller, F. N., 579
Stamp, L. D., 510
Stewart, E. E., 567
Stormonth, J., 591
Strader, H. L., 513
Stratford, R. K., 564, 590
Strause, E. P., 531

Teague, J. U., 515
Thomas, R. M., 551
Tollemache, H., 597
Travis, B., 531
Trinidad Leaseholds, Ltd., 587

U.S. Pipe & Foundry Co., 592

Vesper, H. G., 562
von Zwerger, R., 505
Voorhees, V., 570

Wagner, C. R., 569
Wahlstrom, E., 501
Wallis, J. S., 596
Washburn, E. W., 543
Wearing, C. M., 586
Webster, H. B., 531
Wells, A. A., 591
White, A. E., 531
Widemeyer, R. G., 531
Wigle, W. B., 531
Wilford, A. T., 599
Wilkins, R., 531
Williams, J. F., 585
Williams, W. J., 531
Wilson, C. O., 499
Wilson, R. E., 591
Winkler, K., 568
Winning, C., 551
Wirablanz, R., 550
Wirth, C., 552
Wright, H. F., 528

WORLD PETROLEUM CONGRESS,
London, July 19th to 25th, 1933.

Arrangements are now well in hand for the World Petroleum Congress, which is being organised by the Institution of Petroleum Technologists.

The meetings of the Congress will be held at the Imperial College of Science and Technology, South Kensington, and a Programme giving particulars of the subjects to be discussed has been circulated.

Membership of the Congress is open to all persons interested in the Petroleum Industry, the Membership Fee being 10s.

Apart from the fact that only Members of the Congress will be permitted to attend the meetings and other functions connected with the Congress, they will have the privilege of purchasing preprints of the various papers, and the Report of the Proceedings to be published after the Congress, at a reduced rate.

Full details can be obtained from the Secretary, World Petroleum Congress, Aldine House, Bedford Street, London, W.C. 2.

DESIGNATION OF MEMBERSHIP.

Members wishing to indicate their membership of the Institution are reminded that the correct abbreviations as laid down in the By-Laws, Section III., Paragraph 9, are: Hon.M.Inst.P.T. for Honorary Member; M.Inst.P.T. for Member; A.M.Inst.P.T. for Associate Member; Stud.Inst.P.T. for Student: and Assoc.Inst.P.T. for Associate.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

NOTICES.

The Institution as a body is not responsible for the statements of opinion expressed in any of its publications.

Copyright. Authors of papers and articles are requested to transfer their copyright to the Institution for a period of six months from the date of receipt of the paper. Such transfer should be made in writing when the manuscript is forwarded to the Editor.

Editors are permitted to publish abstracts, providing that acknowledgment is made to The Institution of Petroleum Technologists.

Issue of Journal. The Journal is issued in twelve parts per volume, commencing in January of each year.

Members whose subscription is not in arrear receive the Journal free of cost, and additional copies are charged at the rate of 7s. 6d. per part, unless otherwise stated. A member whose subscription is not paid by March 31st of the year for which it is due is considered to be in arrear.

Changes of Address. Members are requested to notify any change of address to the Secretary.

Papers and Articles. Members are invited to submit papers to be read at the General Meetings of the Institution, and are specially asked to forward articles for consideration for publication in the Journal. Diagrams, illustrations, etc., should be suitable for direct photographic reproduction. Authors are informed that all papers, whether for reading or for publication, will be submitted to a referee nominated by the Publication Committee.

Authors of papers published in the Journal are entitled to receive 25 free reprints of their contribution. Further copies may be obtained on payment, and orders for these should be sent to the Secretary when the manuscript is forwarded to the Editor. The free reprints do not include any discussion which may be published with the paper, but authors may have such discussion included in their reprints on payment of the additional cost.

Galley proofs of the paper to be read at a General Meeting are available at the time of the meeting, but members desirous of receiving such galley proofs in advance should apply to the Secretary.

Binding of Journals. Members desiring to have their Journals bound in cases should send them, together with a remittance of 5s. 6d. per volume, to Messrs. Speaight & Sons, Ltd., 98, Fetter Lane, London, E.C. 4. A charge of 7s. 6d. will be made for binding Vol. 10, 1924. Remittance in all cases must accompany the order.

Abstracts. Abstracts of the more important articles and patent specifications are published with each issue of the Journal, this supplement being paged independently of the transactions. Members and Journal Subscribers desiring to have the Abstracts printed on one side of the paper only can be supplied with these at a charge of 10s. per annum per copy, payable in advance.

Medals. The Redwood Medal is awarded, at the discretion of the Council, as and when desirable, but not more than once each year, to a petroleum technologist of outstanding eminence, irrespective of nationality or membership of the Institution.

A medal and a prize of five guineas is awarded annually by the Council to that Student Member of the Institution who shall, in their opinion, have presented the best paper during the session.

Benevolent Fund. The Benevolent Fund is intended to aid necessitous persons who are or have been members of the Institution, and their dependent relatives.

The Fund is raised by voluntary annual subscriptions, donations, and bequests, and all contributions should be sent to the Secretary of the Institution at Aldine House, Bedford Street, London, W.C. 2. The Fund is administered by the Council through the Benevolent Fund Committee, and all applications in connection therewith must be made on a special form which can be obtained from the Secretary of the Institution.

Appointments Register. A register of members requiring appointments is kept at the office of the Institution for the convenience of firms requiring the services of petroleum technologists, etc., it being understood that the Institution accepts no responsibility and gives no guarantee.

Library. The Institution's Library may be consulted between the hours of 10 a.m. and 5.30 p.m. daily. (Saturdays, 10 a.m. to 12 noon.)

Advertisements. Advertisements are inserted in the Journal, and information as to terms, etc., can be obtained from the Advertising Manager, at the offices of the Institution, Aldine House, Bedford Street, W.C. 2. (Telephone No. Temple Bar 1842.)

Prepaid small advertisements, such as situations vacant and wanted, patents for sale and miscellaneous, are accepted at a charge of 1s. per line of seven words (minimum 4s.). Box number 1s. extra. These should be sent to the Associate Editor not later than the 12th of the month in which it is desired they should appear.

LIST OF ADVERTISERS.

Members are desired when making enquiries or placing orders with advertisers to mention that they have seen their announcement in the Journal.

W. Christie & Grey, Ltd.
A. F. Craig & Co., Ltd.
Duke & Ockenden, Ltd.
Hadfields Ltd.
Hayward-Tyler & Co., Ltd.
National Supply Corporation.
Oil Well Supply Co.
John G. Stein & Co., Ltd.

PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that members send information regarding their movements to the Secretary, for insertion under this heading.

Mr. J. W. Burford is home from Peru.

Mr. J. A. Child has left for Palestine.

Dr. J. A. L. Henderson has returned from Canada.

Mr. J. Henry is home from Peru.

Mr. H. E. King is in Burma.

Mr. G. W. Lepper has returned from Mexico.

Mr. R. H. Mitchell is in Palestine.

Mr. F. S. Smith is home from Mexico.

Mr. F. E. Wellings has left Iraq, and is in Palestine.

Mr. C. A. H. Williams has left for Persia.

We are pleased to announce that the King of Rumania has conferred on Mr. Percy R. Clark the Order of Commercial and Industrial Merit of the first degree.

The Secretary would be glad to learn of the whereabouts of the following members :—E. E. G. Agius, A. E. C. Corbet, E. J. S. Hewitt, A. Maclean, D. J. Pull, P. A. Stiff and R. W. Stiles.

LIBRARY.

The following additions have been made to the Library since May 1st, 1933 :—

British Standards Institution.

— B.S.S., 31–1933. Steel Conduit and Fittings for Electrical Wiring.

— B.S.S., 327, Part II, 1933. Derrick Cranes.

— B.S.S., 482–1933. Wrought Iron and Mild Steel Hooks.

— B.S.S., 483–1933. The Attachment of Circular Metal Cutting Saws.

— B.S.S., 485, Part I., 1933. Tensile Tests on Thin Metal Sheet and Strip.

— B.S.S., 486–1933. Asbestos Cement Pressure Pipes.

— B.S.S., 487–1933. Fusion Welded Steel Air Reservoir.

— B.S.S., 489–1933. Turbine Oils.

Canada, Department of Mines, Bulletin 725. Investigations of Fuels and Fuel Testing, 1930 and 1931.

Journal of the Faculty of Science, Hokkaido Imperial University. Series IV., Vol. II., No. 1. Geology and Mineralogy.

Trinidad, Report of Inspector of Mines, 1932.

The Institution has now been placed on the Loan List of the Science Library, South Kensington, and members of the Institution wishing to obtain books from the Science Library should consult the Institution's Librarian, who will make the necessary arrangements.

The attention of members is also called to the improved facilities available in the Members' Room at the Institution's offices. The number of writing tables has been increased and members will find this room a convenient place, both for consulting books and journals and for conducting their own correspondence.

STANDARD METHODS OF TESTING PETROLEUM AND ITS PRODUCTS.

SECOND EDITION.

Giving full details of revised and new Methods of Test of Petroleum and Its Products.

Price: 7s. 6d. net.

To members of the Institution, marked "Member's Copy," 5s. net.
(Limited to one copy per member.)

REPORTS ON THE PROGRESS OF NAPHTHOLOGY, 1930-1931.

Reprinted from the April and May issues of the Journal, 1932.

Price: 10s. 6d. net.

MEASUREMENT OF OIL IN BULK.

PART I.—STANDARD WEIGHTS AND MEASURES.

Giving authoritative information regarding the fundamental units of weight and measurement in the Imperial, U.S.A., and Metric systems, with a Table of Recommended Contracted Ratios for general use in the petroleum industry.

Price: 2s. 6d. net.

All the above to be obtained from the office of the Institution.

ALDINE HOUSE, BEDFORD STREET, STRAND, LONDON, W.C. 2.

No. 116. Vol. 19.

REPORTS ON THE PROGRESS OF NAPHTHOLOGY, 1932.

Geology of Petroleum

By Professor V. C. Illing, M.A. (Member).

It would be difficult to select any feature in the history of oilfield geology during 1932 as being of outstanding importance. Possibly we are too close to events to assess their relative value, but it would seem that the year has been characterised by a steady advance in many fields of research rather than by the overwhelming importance of some individual discovery. It is good to have some such periods to record, for they allow the orderly description of events, the proper co-ordination of different but related fields of research unembarrassed by the overwhelming importance of some single discovery. Further, they are more truly typical of all scientific progress. The publication may be the outstanding event, but the true history of progress lies in the years of patient preparation.

We have been passing through one of the darkest periods in the history of the industry. High potential production added to reduced consumption have tested it to its foundation, and every branch of petroleum technology has faced drastic curtailment of expenditure. Increased attention has been drawn to methods of oil conservation, the rational development of oilfields as units irrespective of sectional ownership of oil rights, the conservation of reservoir energy and its utilisation in such a way that the ultimate costs of production are reduced. The selling price of oil is low, therefore the petroleum geologist and the field engineer must combine forces to reduce the costs of ultimate production.

It seems but a short time since the geologist was faced with the problems of crooked holes, poorness of geological samples, the wastage of gas. These problems are still with us, but no longer as difficulties that cannot be surmounted. The newer problems are the outcome of a more intelligent realisation of the nature of an oilpool. The intensive study of reservoir conditions has shown how little the geologist knows of the fundamental physical characters of the rocks and of the laws of movement of liquids and gases within them, and an intensive study is now being made of these problems. Unless and until the petroleum geologist can describe an oil reservoir in terms of the thickness, porosity and permeability in its different portions; the oil and gas accumulation in terms of its pressure, ratio of free gas to oil, and quantity of gas in solution; and the water table in terms of its hydraulic head and liberty of movement, he has not collected all the essential data for a scientific scheme of production.

In the theoretical but none the less important subject of the origin of petroleum, a subject which never fails to attract research and opinion, we have had several contributions which are worthy of comment. Mr. J. E. Hackford's paper,[1] published in the Institution's Journal, will arouse considerable comment. It is a plausible attempt to link the origin of oil with the processes of decomposition of algal matter, and the paper is fortified by extensive reference to supporting chemical evidence. The author's conclusions are unique in their visualisation of a process of change in which the products of algal decay are carried in solution to the reservoir rocks, where the process of oil formation is carried to a conclusion. Readers interested in the general subject of origin of oil will also find useful data collected in the recent publication edited by P. D. Trask, entitled "The Origin and Environment of Source Sediments." It is interesting to note that the theory that oil can be produced by pressure, a theory which some felt was comfortably dead and decently buried, has re-appeared in full vigour. The discovery is published in the *Bull. Amer. Petr. Geol.* in a paper by K. Uwotaka.[2] The paper itself contains data which would suggest a considerable amount of caution in drawing sweeping conclusions. It is unfortunate that the author has not felt this restraining influence.

On the question of migration J. Versluys[3] discusses the factors involved in the segregation of oil and gas. His fundamental conception is that of oil and gas separating out from the water circulating in the earth's crust, the cause of this separation being the intermolecular forces responsible for the selection of the coarser strata by the oil and gas. The cognate subjects of permeability in rocks has received the attention of C. M. Nevin,[4] who advocates a standardised method for its determination. This method involves the passage of air under 40 lb. pressure through a core of given dimensions.

The determination of porosity is facilitated by the new method advocated by H. R. Brankston,[5] in which the sample is coated with cellulose.

The peculiar and interesting occurrences of oil in Igneous rocks have always attracted a considerable amount of attention. The

[1] *J. Inst. Petr. Techn.*, 1932, **18**, 74–123.
[2] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 1029–1037; *J. Inst. Petr. Techn.*, 1932, **18**, 458A.
[3] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 924–942; *J. Inst. Petr. Techn.*, 1932, **18**, 416A.
[4] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 373–384; *J. Inst. Petr. Techn.*, 1932, **18**, 198A.
[5] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 915–923; *J. Inst. Petr. Techn.*, 1932, **18**, 416A.

August number of the *Bulletin of the American Association of Petroleum Geologists* contains a very valuable symposium on this subject which collects together an exhaustive account of the occurrences. It is true that a large number of the cases cited are of no economic importance, but this is not wholly the case, and the examples cited by De Goyler from Mexico, by Lahee from the Argentine, and by Sellard from the Gulf Coast of Texas, show that in some cases the porosity of an igneous rock is sufficient to allow it to act as a reservoir rock for petroleum. For this interesting collection of data we are largely indebted to the enthusiastic work of Sydney Powers, one of the last services to geology and to petroleum that this indefatigable and devoted worker was able to contribute.

The study of oilfield waters is discussed by D. Chahmazaroff,[6] who suggests a new diagrammatic representation of the results. This is based, firstly, on the salinity (as the gravity of the solution), and secondly on the temperature (as the geochemical degree, *i.e.*, the rate of change of temperature with depth). Another contribution on the subject of water, but from a different standpoint, is that of E. K. Soper,[7] who draws attention to interesting parallels between the behaviour of the water table and the presence of buried structure. He notes that these agreements are often largely the result of the topography, but claims that in any case bulges in the water table are always worthy of investigation, though in themselves they are not reliable proof of anticlinal conditions.

Probably no subject in oilfield structures is more interesting or elusive than the question of salt domes. Within recent years both the American Association of Petroleum Geologists[8] and our own Institution[9] have contributed a symposium on the subject. The year that has passed witnessed a gathering of the Continental geologists at Hanover in May, and the papers contributed were very largely a study of the salt dome phenomena in the German Basin. This meeting will receive further comment in dealing with regional developments.

In a discussion on Salt Flowage, R. A. Jones[10] draws attention to the overhang of the salt at Barber's Hill, and follows European opinion in attributing the condition to the plasticity of the salt mass which forms the core of the structure. Of

[6] *Mat. Grass.*, 15.8.32, (292), 9587–89; 15.9.32, (293), 9615–17; *J. Inst. Petr. Techn.*, 1932, **18**, 421A.

[7] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 335–360; *J. Inst. Petr. Techn.*, 1932, **18**, 198A.

[8] "The Geology of the Salt Dome Oilfields," by De Golyer and others.

[9] *J. Inst. Petr. Techn.*, 1931, **17**, 252–383.

[10] *Oil Weekly*, 1.8.32, **66** (7), 31–36; *J. Inst. Petr. Techn.*, 1932, **18**, 373A.

particular interest is the contribution by Prof. Stille[11] on asymmetrical folds with reference to German salt bodies. After describing the fundamental regional conditions around the German basin, the author points out that both pressure and tension have contributed to the regional structure, and that the salt flowage has resulted from and been governed by these two conditions. He formally retreats from his previous uncompromising championship of lateral pressure as the sole cause of salt movements, and allows the play of isostatic forces as a contributory cause. After discussing conditions in the Gulf States of Texas and in the German Basin, Stille concludes that in each case lateral pressure and isostatic forces have played a contributory part, but whereas in Germany the pressure conditions were dominant it would appear that in the Gulf States they were subordinate to the isostatic adjustments.

Turning now to the regional aspects of oilfield geology, we have the perennial discussion of oil in England resuscitated by an article of Dr. A. Wade,[12] who registers a favourable opinion of certain selected areas in the Weald for the discovery of oil in Mesozoic rocks.

Much attention has been focussed on the German developments, particularly those of Thuringia, where oil has been found for the first time below a salt mass. The production at Folkenroda has been in some particulars disappointing. The oil is largely localised in fissures and joint planes, and production is very irregular. Much of the drilling has been abortive and operations have been seriously hampered by fire in the mine. There can hardly be the shadow of a doubt that the oil originates in the Permian, or even perhaps in lower strata, and this has been seized on by German geologists as sufficient grounds for a complete *volte face* in their views as to the origin of the oil in the German Basin. The theory is freely circulated and has gained many adherents, that all the oil of the German Basin is of deep seated origin. It is claimed that it has migrated up from below, taking advantage of the fractured conditions adjoining the salt plugs and has saturated suitable reservoir rocks in the Jurassic and Cretaceous. A new broom sweeps clean, and this new theory, by virtue of its simplicity, has received ready acceptance, but the writer is on safe grounds in prophesying that source rocks within the Jurassic and Lower Cretaceous will be accepted later as more in accord with the general evidence. It is the rule rather than the exception to find that the cycle of petroleum formation repeats itself in the same area at widely different epochs. It is unsafe, therefore, to deny the

[11] *Amer. Assoc. Petr. Geol.*, 1932, **16**, 169–177.
[12] *Oil News*, 1931, **29**, 91–92.

probability of there being several source rocks in the German Basin both above and below the salt.

The active prosecution of the search for petroleum in Germany has been continuous, even throughout the depression, and geological, geophysical, and drilling work has increased the number of salt domes discovered and expanded production in the proven fields. No new fields have, however, been discovered, but it may be confidently anticipated that these will come in due course. The Geological Congress at Hanover brought to light a considerable wealth of important geological information on the Thuringia occurrences, and on the intimate adjustments of movements, erosion and sedimentation on the borderland of the German salt domes. To those who read the data in detail, the facts presented will bring a picture of these salt domes as local sources of disturbance in the basin of sedimentation. They have their own local history during Mesozoic and Tertiary times, though they still reflect the broader movements present in the main basin. One might almost say that a salt dome becomes a delicate indicator of the stress variations during Mesozoic time in the region. One excellent example of this is provided by the western flank of the Nienhagen salt dome described by E. Strobel, but those interested in these phenomena should refer to the collective publication.[13]

A very complete account of the oil occurrences of France has been given by F. G. Clapp.[14] All of his subject matter is available in other European publications, but is not so readily accessible to many readers. It may serve to arouse interest in French territory as a source of future oil, but at the moment, apart from the Pechelbronn area, the only commercial supplies of bituminous material available are the various asphalts and asphaltic limestones, of which those of the Gard are the most important.

Among the lesser known oilfields of Southern Europe, a short account of the oil in the Parma District, Western Italy, has recently been given, and in the pages of our own Journal Dr. A. Wade[15] describes some geological features of Zante, which contains interesting oil shows but no large occurrences. Of the more important fields of Europe there is a new description of some of the better known oilpools of Poland which brings information up to date.[16]

---

[13] "Die Erdoltagung, der Deutschen Geologischen Gesellschaft in Hannover," 5–7 Mai, 1932.

[14] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 1092–1143; *J. Inst. Petr. Techn.*, 1933, **19**, 2A.

[15] *J. Inst. Petr. Techn.*, 1932, **18**, 1–28.

[16] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 1061–1091; *J. Inst. Petr. Techn.*, 1933, **19**, 3A.

E. Dimitriu[17] discusses various oil problems in Rumania from the prospecting to the development phase. He lays stress on the need for a careful study of the physical nature of the formations and a careful conservation of the gas oil ratio. These suggestions are parallel with production practice in other areas.

The search for oil in Northern Africa has been admirably summarised by H. de Cizancourt[18] in a contribution to the *Bull. Amer. Pet. Geol.* He describes the work already done in Morocco, Algeria and Tunisia, and after an account of the relevant geological features indicates that the results are now being reviewed with a view to active prosecution of the search if conditions warrant it. In the area of the Egyptian oilfields we have a notable contribution by T. S. Bowman,[19] in which the geological history of the area bordering the Red Sea is discussed. A very complete account is given of the numerous tests that have been made for oil and a new description of the Hurghada field is very welcome.

Of other areas which receive special attention brief reference may be made, because of the importance of the subject, to E. C. Andrews'[20] paper on "Prospecting for Oil in Australia and New Guinea." After reviewing the results in each of the states the author, on general geological principles, and in spite of the lack of success, concludes that oil ought to occur in the great basins of the mainland and on the northern marginal basin.

Among the older fields of the United States we have a description by W. L. Russell[21] of the oil and gas pools of Western Kentucky. The interest of this paper is not purely local, for it has an important section on the development of porosity in limestones and dolomites.

Turning now to the Middle West, the zone of most active field operations at the present time, there is a wealth of new data to which it is not possible to do justice in a short discussion. However, particular attention should be drawn to the masterly treatise of Van der Gracht,[22] on the Permo-Carboniferous Orogeny in South Central United States. This paper actually appeared near the end of 1931, but somewhat late to receive notice in the Progress Report for that period. It will be welcomed by students of tectonics

[17] *Ann. Min. Roum.*, 1932, **15**, 239–243, 281–287, 363–370; *J. Inst. Petr. Techn.*, 1932, **18**, 417A.
[18] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 443–467; *J. Inst. Petr. Techn.*, 1932, **18**, 239A.
[19] *Government Press*, Cairo, 1931, p. 353; *J. Inst. Petr. Techn.*, 1932, **18**, 289A.
[20] *Econ. Geol.*, 1932, **27**, 365–379, 471–486; *J. Inst. Petr. Techn.*, 1932, **18**, 420A.
[21] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 231–254; *J. Inst. Petr. Techn.*, 1932, **18**, 148A.
[22] *Bull. Amer. Assoc. Petr. Geol.*, 1931, **15**, 991–1057; *J. Inst. Petr. Techn.*, 1931, **17**, 495A.

and oilfield geology alike, and is a welcome indication of the tendency among geologists in America to pay more attention to broad structural and stratigraphical conditions as being of equal importance to the study of local structure. It is interesting to note that the author, after an analysis of the data, concludes that there is a distinct resemblance between the Appalachian movements and those of the Alpine type of tectonics, involving strong overthrusting and marked asymmetry. This is in direct contrast to the normal American conception of Appalachian fold structures, but the older conception has already been attacked as untenable, and there is certainly strong grounds for accepting marked overthrusting in many of the areas. In justice to the work of American geologists, it must be remembered that the areas to be mapped are vast, and the number of workers, though large, is quite inadequate for such broad territory. The result is that detailed geological field mapping in the European sense is hardly attempted save in selected areas.

One of the most outstanding events in the North Mid-Continent in the last few years has been the development of the Oklahoma City field. This has now been described by D. A. McGee and W. W Clawson,[23] and its structural and geological history have proved to be of great interest. The pool is one further example of the importance of the structure within the basement as a determinant of the structures in the overlying Pennsylvanian and Permian. This basement underwent folding and deep erosion prior to the deposition of the Pennsylvanian as a soft overlying blanket. The later history seems to indicate an adjustment of deposition and movement, and the latter can be best described as sagging around the crestal maxima, producing fold forms in the younger beds over stronger fracture folds in the basement. One may safely predict that when the geological history of these fields has been gathered into one story, it will form one of the most illuminating chapters in the history of oil geology and an outstanding contribution to the study of earth movement and sedimentation.

One other paper deserves comment as a further step in this direction; the discussion of the Burbank Sand in Kansas by G. Weirick.[24] Conditions appear to have been dominated by the presence of the Granite Ridge in Central Kansas in Upper Carboniferous times. This ridge trended north south, and along its eastern margin sand banks were developed parallel to the old shore line.

[23] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 957–1020; *J. Inst. Petr. Techn.*, 1932, **18**, 456A.

[24] *Oil Weekly*, 22.8.32, **66** (10), 25–28; *J. Inst. Petr. Techn.*, 1932, **18**, 374A.

The Burbank Sand represents these conditions. The present structure is a simple monocline, and most of the oilpools developed in this sand are claimed to be due to accumulation of oil up dip in the recesses of the sand along its eastern margin.

The Ozark Mountains will always attract geologists interested in the broad features of tectonics and sedimentation. They are the unburied counterparts of many structures both north and south, which can only be studied slowly and partially by piecing together the results of borings. Here, on the other hand, the once buried ridges are now partially exposed, and along the edges of the exposure the relations of the mantle to the basement are capable of field interpretation. An exceedingly interesting account of these features has recently been given by C. L. Dake[25] and J. Bridges. It is noteworthy that the authors conclude that many of the irregularities of dip and strike in the overlying mantle are due to depositional irregularities, the floor having played its part in the guidance of sedimentation. This is as it should be, and it is worthy of comment that in the case of deposition of sands and clays off shore on an irregular sea bottom, no other result would be possible. Yet geologists, as a whole, do not appear to realise this, and having hardly considered in detail what takes place during and after sedimentation are liable to produce simple mental pictures which are far removed from the facts. The wealth of detail nature has presented for our inspection is far greater than we can achieve, either by experiment or by deduction. Therefore, the geologist's method of attack by observation of results, though it reaches the goal by a slower and more difficult journey, is abundantly worth while in the wealth of detail ultimately presented. Cases such as the examples described in the Ozark Mountains are full of illuminating data for application elsewhere.

The outstanding, not to say menacing, rise in production of the East Texas fields has concentrated attention on these oilpools. Many aspects of the geological conditions have been discussed, but a detailed account of the new pools has yet to be published. One of the most important aspects of these new pools is the behaviour of the water table. In such extensive sand bodies, the adjustment of water level to the changes of pressure must be very considerable; one may, therefore, anticipate an extensive influx of water as the pressure diminishes. It is sometimes forgotten in discussing the movements of edge water that these are governed not only by the pressure changes within the reservoir and by its permeability, but also the total extent of permeable

[25] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 629–652; *J. Inst. Petr. Techn.*, 1932, **18**, 334A.

rock involved—*i.e.*, the mass of rock containing both gas-oil and water which is in one and the same pressure system.

A striking example of overhang on the edge of a salt dome has been described recently by S. A. Judson and others[26] in the case of the Barbers Hill dome. At first it was thought that production was being obtained from below the salt mass, until it was realised that this was really marginal production and that the margin of the dome was locally overturned. Geologists conversant with European salt dome areas, such as Germany and Roumania, will readily instance parallel cases which have been known for many years, and it is by no means so unusual as the authors appear to consider. It is curious how little is known among American geologists of the wealth of geological information available in European literature.

There are no outstanding discoveries to chronicle in the fields of the Rocky Mountains belt in U.S.A. and Canada or in the Californian area. An interesting example of a new geological view-point is in the paper by W. Stalder,[27] dealing with the regional structure of the Kettleman Hills, Wheeler Ridge and Marysville Butte, in which he claims that the arcuate structures bordering these big structures have influenced regional migration and caused large oil accumulation.

The question of oil in Cuba receives some attention from J. W. Lewis[28] in a paper on this island. This gives a general account of the geology of the island and discusses the very considerable evidences of petroleum. The occurrences are full of problems relating to the migration of petroleum and are well worth detailed study. Venezuela and Trinidad have been in the doldrums during the period under discussion. Drilling activity has been severely curtailed, and the industry in this quarter of the globe has suffered a check from which it is now slowly recovering.

Of the broader questions which affect geology and geologists in general, there is one feature in particular which is worthy of notice. The sciences of geology and geophysics are slowly but surely being properly co-ordinated. There has been much confusion and waste of effort in the past, for which neither side can wholly escape some share of the blame. On the one hand the geophysicists, using a new weapon and with the training of physicists were unaware of the geological pitfalls into which they were plunging. Visualising the upper crust as a structure of physical components and unaware

[26] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 469–482; *J. Inst. Petr. Techn.*, 1932, **18**, 239A.
[27] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 361–371; *J. Inst. Petr. Techn.*, 1932, **18**, 197A.
[28] *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 533–555; *J. Inst. Petr. Techn.*, 1932, **18**, 333A.

of the enormous complexity of the geological record, they were bound to find the interpretation of their results both difficult and elusive. The geologist, on the other hand, was sceptical of the claims of geophysics, and has but slowly come to realise that it is in fact a very useful though expensive weapon. The proper co-operation of the two sciences usually means that the geologist appeals to the geophysicist for help in particular problems. The best geophysical method of attack is applied after consultation, and the interpretation of the results involves the elimination of some geological possibilities and the selection of the solution which best fits the physical facts. There are, of course, many more definite lines of attack, such as the discovery of salt domes in which geophysical exploration is carried out independently, but it ought to be realised that it is in co-operation that each science stands ultimately to gain.

Geophysics.

By Oscar Weiss.

The principles of the different methods of geophysical prospecting have already been given both in the Journal of this Institution[1] and in various text books.[2] The purpose of this paper is to analyse the developments of the last three years in methods and instruments and to survey future possibilities.

The present slump in field work has given an opportunity for a much needed careful study of practical field results compared with theories and laboratory experiments. This work is of great practical value and will clear away much of the mystery which has surrounded the subject.

Although one may still meet a certain number of technical men who are somewhat sceptical, there is no doubt that geophysical methods are established factors in oilfield work and that the future will see them playing an increasingly important part not only in exploratory work, but also in many production problems. They have already been adopted by geologists for obtaining additional information about sub-surface conditions on producing fields where all possible surface geology and records from wells have already been correlated. For this purpose a number of different geophysical methods are used, advantage being taken of making observations in the wells themselves as well as on the surface with a view to obtaining further data on exact correlation of the strata and information as to the porous beds which act as oil reservoirs.

Such work has particular value both on account of the close check it gives on geophysical results and on account of the close collaboration it entails between geologist and geophysicist.

Much was lost in the earlier geophysical work by the failure to realise or perhaps in some cases to admit the great extent to which the geophysicist has to rely on the geologist for his information. Although some of the larger oil companies early realised the possibilities of geophysical methods and organised their own departments, much of the work was carried out by independent geophysical companies and the tendency was to treat geophysics as separate from geological work. It is now more fully realised that geophysical work is rather an additional weapon to be placed in the hands of the geologist than an end in itself.

The exploration of buried structures by different methods, well surveying, analysis of production curves are all integral parts of modern oilfield organisation which need the attention of specially

[1] W. H. Fordham, *J. Inst. Petr. Techn.*, 1930, **16**, 97–107.

[2] Broughton, Edge and Laby, "Geophysical Prospecting," Univ. Press, Cambridge, 1931; "Handbuch Der Experimentalphysik," Leipzig, 1930; "Les Méthodes de Prospection du Sous-Sol," E. Rothe, Paris, 1930.

trained men. Although recent years have shown considerable improvements, the training of such men is a problem not yet fully solved. At present a number of scientific institutions are engaged in research work on new methods and instruments, but there are only a few which actually train practical geophysicists. While the research work should rest with the physicist there is at the same time need for close co-operation with the geologist who is presenting the problems and whose information is essential in the final geological interpretation of the work. In practice the actual geophysical prospecting work should be under the control of the chief geologist of the oil company, with a responsible geophysicist at the head of the geophysical work.

The last few years have shown that the problems of the training of the geologist in geophysics are now being faced. A number of valuable publications have presented the results of the investigation of mathematicians and physicists in a form easily understood by the geologist. The use of graphical methods have been long adopted by the practical geophysicist as means of saving time and labour. The same graphical methods should present no difficulties to the geologist and would enable him to check and control the work of the geophysicist. It is, therefore, of the utmost importance to further the working out of these graphical methods, accounts of several of which have already been published in English, American, French, German, Hungarian and Russian literature. At the same time no company should rely upon men who are simply using the final results of research given in this form. While such practical methods help the geologist in his check and control, the actual geophysical work should be carried out by specialists who are able to follow the latest developments in the different methods.

The development in the construction of instruments in recent years has been confined to more or less important modifications of existing types. No new method has been put into practice, although the exploitation of deep horizons and the costly nature of deep drilling has set up new requirements in the application of geophysics. These requirements were partly met by increasing the sensitivity of the instruments, the accuracy of the measurements and partly by increasing the reliability of geophysical information by combining the results of different methods. In connection with this it is interesting to recapitulate some experiences with geophysics on the Gulf Coast of Texas and Louisiana. Here the same areas have been twice surveyed by torsion balance and four times by seismograph. In each case improvements in the prospecting methods and in their interpretation showed up the inaccuracy or limitation of the work previously done.[3]

[3] D. C. Barton, Review of Geophysical Prospecting, *Bull. Amer. Assoc. Petr. Geol.*, 1930, **14**, 1105–1143.

The development of higher accuracy and the combination of different methods is the characteristic advancement of recent years compared with previous practice. The following is a brief survey of the main developments in different methods :—

The Torsion Balance method has had the advantage of being based on exact theory and there is now much accumulated data which has been actually checked by drilling. The limitations of this method are now more or less understood, and, provided these limitations are taken into account, it has advantages over other methods which so far have suffered from a lack of exact theory and accumulated data checked by drilling. Under favourable conditions the Torsion Balance will reliably locate geological structures and delineate their boundaries. For depth determination, however, more detailed knowledge of the distribution of densities is necessary. The influence of large distant structures and the effect of deep major structural features upon the local anomalies is now carefully taken into consideration when making interpretations. The so-called " regional gradient " is determined and the ' shift of crest " is eliminated. Some clever methods have been developed for this purpose.[4] The effect of structural compaction was studied on areas where definite gravity anomalies have been observed although core samples have not shown any inherent density differences.[5] Refined methods of interpretation were applied to cases where it was found from core samples that the density varied with the depth within the same stratigraphical formation. The density differences here were supposed to be a function of the co-ordinates and the gravity effects have been calculated accordingly.[6] A special mechanical integrator was constructed for determining the gradient and curvature values of bodies with any given cross-section.[7] The form and behaviour of the gradient curve and of the differential curvature was analysed and for their interpretation new methods have been designed and worked out for simple geometrical features, from which the more complicated geological structures may be constructed.[8]

In the research on the further improvement of the Torsion Balance the most significant are the investigations on the disturbances of this instrument.[9] A great deal of work has been done on the

[4] R. Vajk, " A Regionalis Gradiens Problemaja," Budapest, 1932.

[5] R. H. Miller, Analysis of Some Torsion Balance Results in California, *Bull. Amer. Assoc. Petr. Geol.*, 1931, **15**, 1419–1429 ; *J. Inst. Petr. Techn.*, 1932, **18**, 42A.

[6] A. Belluigi, Particolari Aspetti Gravimetrici di Alcuni Subpadani, *Gerl. Beitr. f. Geoph. Erganz.-helft, f. Angew. Geoph.*, Vol. 2, No. 2/3, 1931.

[7] *Zeitschr. f. Inst.-kund.*, 1932, 289–299.

[8] H. Shaw, *Trans. Am.I.M.M.E. Geoph. Prosp.*, 1932, 271–335.

[9] Stephen Rybar, Az Eotvos-fele Torzios Inga Zavarairol, *Math. es Term. Tud. Ert.*, Budapest, 1932.

problem of the short period Torsion Balance, but so far without any definite result. The size of the instrument was reduced by a modification of the swinging system and by using Tungsten torsion wires instead of Platinum alloys. The latest development is an instrument with three beams (an arrangement already used by Eötvös) and with a novel swinging system consisting of an inclined rod with small gold weights on each end.[10]

In view of the advantage of the pendulum for the direct determination of Δg (the relative value of the gravity force) an attempt was made to reach the accuracy of the Torsion Balance; this would mean an increase in accuracy from $2 + 10^{-6}$ to $2 + 10^{-7}$.[11]

Under favourable conditions in spite of its limitations the gravitational measurements obtained by the use of the Torsion Balance remain indispensable in getting reliable data about hidden underground structures.

The Seismic method in recent years has continued its rapid development and attained unsurpassed importance especially where the accuracy of the depth determinations are concerned. The initial experimental period is now passed and the instruments and methods are used in the light of long established theories of earthquake seismics and the problems are more delicately handled. The range of the refraction (diffraction) method was extended to a depth of 7500 ft. This greater depth made necessary a higher accuracy of the measurements. The signals are now transmitted by wireless and the distances are carefully surveyed. Time marks of a 1/100 second are used and the explosives are buried in holes. The seismographs have a higher sensitivity and more attention is paid not only to the first impulse but also to the late arrivals on the seismogram. Next in importance to the locating of structures at great depth, the refraction method is used for such detailed work as determining the mushrooming of salt domes utilising existing wells, a work which involves a determination of the distortion of the wave front due to the increase of velocities with the depth.[12] Attempts were made to apply the method to loosely consolidated sediments where the velocity of the elastic waves is a continuous function of the original overburden. To meet the requirements of this work and get maximum accuracy of time and minimum amount of explosives, the frequency of the seismographs has to be carefully

[10] B. Numerov, Torsion Balance with Three Beams, *Bul. l'Inst. Astr.*, Leningrad, No. 30, 1932.

[11] *Veroeff. d. Reichsanstalt f. Erdbebenforschung*, Jena, No. 17, 1931.

[12] B. McCollum and W. W. La Rue, Utilising of Existing Wells in Seismograph Work, *Bull. Amer. Assoc. Petr. Geol.*, 1931, **15**, 1409–1417; *J. Inst. Petr. Techn.*, 1932, **18**, 42A.

considered.[13] The influence of the pressure of the overburden upon the velocities was also determined on laboratory samples and agreed well with field data.[14] The direction and approximate magnitude of the dip is stratified media were measured by using seismographs and the crests of buried folds were located. It should be noted that this investigation does not involve two media of different elasticity, but the same stratified medium in which the apparent point-to-point velocity is different—normal to and parallel to the bedding planes.[15]

The ordinary refraction method was based on assuming straight wave paths within each formation, but in practice, profiles with curved time-distance graphs often occur. Formulæ for the practical treatment of this problem were developed based on the theory of similar problems in earthquake.[16] An intimate connection between the variation of the velocity on a limestone and the productivity of different parts of an oilfield in Persia was proved in connection with some delicate seismic work.[17]

An important development in seismic work was the introduction of the use of seismic reflection in oil prospecting. It should, however, be understood that this can be only applied where a good reflecting surface exists and that the identification of the reflecting surface is not easy. On the other hand, this method reduces the amount of explosives and furnishes very accurate depth determination. Under favourable conditions, with charges of 2–3 lb. of dyanmite, differences of the relief of 25–50 ft. to the mile may be detected at a depth of 5000 ft. The cost of the explosives is only 3 per cent. of the total operating costs. In this type of work the accuracy of the time determination should be 1/1000 of a second. The identification of the reflections in the seismograms is facilitated by arranging the seismographs in groups and by "tuning" the frequency of the instruments according to the local requirements, depending upon the "unrest of the ground," the nature of the rocks and the depth of the reflector.[18] The instruments used in reflection method may be either electric or mechanical seismographs set up on the surface or buried in holes.

[13] F. Rieber, Results of Elastic-wave Surveys in California and Elsewhere, *Bull. Amer. Assoc. Petr. Geol.*, 1930, **14**, 1557–1571.

[14] T. C. Richards, On Elastic Constants of Rocks with Seismic Application, *Phys. Soc. Proc.*, Vol. 45, No. 246, London, 1932.

[15] B. McCollum and F. A. Snell, Assymetry of Sound Velocity in Stratified Formations, *Physics*, Vol. 2, No. 3, 1932.

[16] M. Ewing and L. Don Lee, *Trans. A.I.M.M.E. Geoph. Prosp.*, 1932, 263–270.

[17] J. H. Jones, The Diffraction of Elastic Waves on the Boundaries of a Solid Layer, *Proc. Roy. Soc. A.*, Vol. 137, 1932.

[18] E. McDermott, Application of Seismography to Geological Problems, *Bull. Amer. Assoc. Petr. Geol.*, 1931, **15**, 1311–1334; *J. Inst. Petr. Techn.*, 1932, **18**, 40A.

For exact depth determination the velocity in the upper layers should be accurately measured. Boreholes may be used for this purpose or where no wells are available the method of curved paths is very valuable. Correction has to be made in the calculations for the weathered zone and for the differences in elevation.[19] The mathematical theory of the seismic reflection can be formulated and solved by the use of the theory of images and the amount of reflected energy can be calculated for given rocks based on theories identical with those developed on similar problems in earthquake seismology.[20]

The possibilities of the reflection method are not exhausted by the above-mentioned examples; it is not unlikely, for example, that with the increase of accuracy and sensitivity reflections from the surface of oil, water and gas may be utilised in the future.

The recent developments in the earth-magnetic methods have not opened up any new possibilities in oil prospecting. The investigations have, however, contributed to the clearer understanding of the influence of different factors involved in the measurements and have also brought out new complexities. It is now accepted that the magnetic method of prospecting can only occupy a secondary place in the search for oil and should be used in combination with other methods, in preference with the Torsion Balance. The serious limitations of this method are not confined to the depth determination only, but also to its use in locating structures. The latter problem is often viewed with over-confidence due to a popular knowledge of earth-magnetism and to the attractive simplicity of the measurements.

The application of this method for locating sedimentary structures is based on the assumption that the structure of sedimentary formations is related to the configuration of the basement rocks, granite ridges and igneous intrusions, an assumption which may be entirely false. On the other hand, slight differences in the magnetic properties of sediments can be detected by sensitive instruments, due to the distribution of magnetic minerals in the sediments themselves, and these slight differences in magnetic susceptibility make it possible to find "magnetic marker beds" for tracing structural features beneath the alluvium.

In the early magnetic prospecting it was considered that the high value of vertical magnetic intensity always reflected a corresponding area of relatively high relief. This simple relation does not always exist. Difficulties arise from the fact that in many areas

[19] A. M. Rutherford, A.I.M.M.E. Tech. Publ., No. 486.
[20] I. Roman, *Trans. A.I.M.M.E. Geoph. Prosp.*, 1932, 460–486; H. Blut, *Zeitschr. f. Geoph.*, No. 3–4, 1932.

the rocks possess strong permanent magnetism; furthermore, the orientation of this magnetism is not uniform. For example: the crystalline rocks of Finland and North Sweden produce strong negative magnetic anomalies while in other parts of Europe they show positive magnetism.[21] It may be supposed that the permanent magnetism of a rock is due to the magnetic crystals distributed in the rock and oriented according to the direction of the magnetic field existing at the time of the solidification of the rocks. This direction may be quite different from that of the earth's field now existing. The magnetisation of the igneous rocks depends greatly on the intensity of the magnetic force,[22] on the process of cooling and the mechanical stresses undergone in course of their geological history.[23]

The above consideration explains why structural "highs" and magnetic "highs" in many cases do not coincide and that strong negative magnetic anomalies have been observed over structural uplifts. This abnormal magnetic polarisation has now been studied and is considered to be due to such causes as: (*a*) the dip of the formation; (*b*) effect of differential cooling; (*c*) magnetism induced in a smaller body by a larger magnetic mass; (*d*) decrease in the thickness of the magnetic formation; (*e*) overturning of the formation as a whole; (*f*) overturning of solidified portions in plastic lava; (*g*) mechanical stresses.[24] These above-mentioned complications do not affect sedimentary rocks or some of the weakly magnetic acidic igneous rocks. For the interpretation of results over such formations the values of the magnetic susceptibility must be determined. This would best be done on rocks *in situ*, but no satisfactory method has been developed so that laboratory determinations are made on solid core samples or on pulverised material.[25] While such determinations may not be true in an absolute sense, they may be true in a relative way. Such measurements have proved the increase of susceptibility with the increase of magnetic mineral content.[26] These laboratory determinations should be made in connection with field observations on outcropping beds. Some interesting studies of this kind were made on the salt dome areas of north-west Germany, where shallow salt domes and especially their anhydrite cap-rock have shown definite magnetic anomalies,[27] and it was found that in the North-German Basin magnetic isanomaly maps do reflect the

[21] A. Nippold, *Archiv. d. Erdmagnetismus*, No. 6, 1927.
[22] P. Weiss, *L'Eclairage Electrique*, 1896, Vol. 7, 487.
[23] H. Nagaoka, "Magnetization of Nickel," Imp. Coll. of Sc., Tokyo, 1889.
[24] A. C. Heiland, *Trans. A.I.M.M.E. Geoph. Prosp.*, 1932, 234–236.
[25] W. M. Barrett, *Trans. A.I.M.M.E. Geoph. Prosp.*, 1932, 216–233.
[26] D. M. Collingwood, *Bull. Amer. Assoc. Petr. Geol.*, 1930, **14**, 1187.
[27] E. Kohl, *Jahrb. d. Reuss. Geol. Lands.-anstl.*, 1928, Vol. 49.

regional geology. Their construction over alluvial plains would be of great importance to the oil geologist, but no detailed information can be expected from such maps, and the supposed indications of structures have to be considered with caution.[28]

The determination of the depth and shape of the disturbing body remains in most cases an unsolved problem in magnetic prospecting, although some good work has been done by building up such problems from the analysis of single magnetic poles.[29]

The development in instruments was marked by the construction of a new compensated magnetometer of the Schmidt type which practically eliminates the effects of temperature changes,[30] while a new magnetometer was built on the principle of the dip needle for use on strong magnetic anomalies in reconnaissance work.[31]

In spite of all the good work done in the past three years, the magnetic method has not gained any new importance in oil prospecting. There is reason to suspect that with the present trend of developments involving greater depths and requiring more accurate geophysical information, the magnetic method will lose importance.

The application of electrical prospecting methods in oil problems is chiefly a development of the last few years, following on earlier work carried out with varying success on the location of ores and minerals. While there has been appreciable progress made, some serious limitations must not be overlooked. There is still a lack of an exact theoretical treatment of the problems and most of the reported results are from areas where the conditions have been known from previous geological and geophysical investigations. It is one thing to prove the relation between known geological conditions and electric results and another thing to determine unknown conditions from observed data. So far, electric methods have had little use in prospecting unknown areas and their application is limited to the obtaining of additional information over more or less known conditions. The value of this information, furthermore, is limited by the comparatively shallow depths up to which reliable data can be obtained.

All the present electrical methods depend upon the different conductivity of different strata. It is true that high frequency electromagnetic methods do respond to differences in the dielectric constants, but the depth penetration of these methods is small,

[28] O. Keunecke, *Gerl. Beitr. f. Geoph. Erganz.-heft. f. Angew. Geoph.*, 1932, Vol. 2, No. 4.
[29] A. Nippold, "Verwertung Magnetischer Messungen zur Mutung," Berlin, 1930.
[30] C. H. Heiland and W. E. Pugh, A.I.M.M.E. Tech. Pub. No. 483.
[31] N. H. Stearn, *Trans. A.I.M.M.E. Geoph. Prosp.*, 1932, 169–199.

and therefore they have little importance. The resistivity of rocks in oilfields varies from 20 to several million ohms, and the dielectric constants from one to ten.

All the information given by electrical methods are in terms of resistivity, but resistivity is not a reliable constant of the rock, since it depends on the pore volume, water content and ion concentration. With the existence of these unknowns and the unknown depths, the identification of the so-called "electrical marker" beds is very difficult, especially where several good conducting beds are present and where the geological conditions are disturbed. Unfortunately, the assistance of electric methods is mainly sought for obtaining additional details over disturbed geological structures.

The depth limitation of these methods is about 1000–1500 ft., but these greater depths are only reached in locating salt water horizons with very high conductivity over the very poorly conducting salt domes. By tracing salt water horizons it is possible to locate the top of salt domes and also to eliminate certain zones on the flanks where, because of the presence of salt water, the prospects for oil are unfavourable. The tracing of beds of marked electric conductivity is mostly done to depths of 500–600 ft., and deeper deductions from this type of work are based on assuming perfect conformity between the shallow beds and the deeper strata, a condition which does not always exist.

In spite of all the above limitations, it has been claimed that the direct location of the oil has been achieved; it seems that in these cases it was more the elimination of areas coinciding with salt water horizons than the direct locating of oil, and according both to experiments and theory the effect of a poorly conducting, thick sand or limestone bed cannot be distinguished from the effect of comparatively thin oil sands.[32]

The theories of electrical methods are based on the assumption of isotropy of the media, but small irregularities near to the surface have a strong influence upon the results, especially in the potential drop measurements. Besides, it was found that in stratified media the ions have greater mobility parallel to the strata than perpendicular to them, and therefore they are anisotropic electrical conductors. The theory of the determination of the electric field in anisotropic media from that in an isotropic space was worked out for some simple cases.[33] The anisotropy also disturbs the phase relations in the electromagnetic methods. This complication

[32] *Oil Weekly*, 1930, **58** (6), 34–36.
[33] R. Maillet and H. G. Doll, *Gerl. Beir. f. Geoph. Erg.-heft. f. Angew. Geoph.*, 1932, Vol. 3, No. 1.

was investigated and overcome by using low frequency currents.[34] The method of interpretation of earth-resistivity measurements was further developed by finding the principles of an exact mathematical treatment.[35] The depth determination is now made by the analysis of the resistivity curves involving not only the sharp breaks, but also the treatment of the smooth curves which are often obtained in practice.

A more sensitive method for the determination of depths was developed, especially suited for detecting horizontal formation boundaries. This method is measuring the potential-drop-ratios by means of bridge arrangements. It makes the detecting of small differences in the apparent resistivity possible and dispenses with the troublesome cable connection to the power electrodes and yields curves which are well suited for interpretation.[36]

The influence of the shielding effect was studied both in potential-drop and electromagnetic measurements. A good conducting, thin surface layer may mask completely the finer changes in potential-drop measurements, while its effect on the electromagnetic field is negligible. Considering that in practice good conducting surface layers are the more frequent, preference should be given to the electromagnetic methods for more detailed exploration of greater depths.[37] The penetration can be increased by using low frequency currents. By means of electromagnetic methods the configuration of good conducting layers can be determined; this configuration, however, often may not represent geological structures. This especially applies to the water table, so that electromagnetic methods should only be used for the investigation of strata below the water table.[38]

In all electromagnetic investigations the effect of topography and the magnetic field due to the cable lines of the current and to the anisotropy of the media should be carefully eliminated. The extent of anisotropy is shown by laboratory determinations on a Devonian shale, in which the conductivity ratio was 1 : 4, parallel to and perpendicular to the bedding.[39]

---

[34] Max Mueller, *Gerl. Beitr. f. Geoph.*, Vol. 30, No. 1–2, 142–195.

[35] J. N. Hummel, *Trans. A.I.M.M.E. Geoph. Prosp.*, 1932, 392–422; D. O. Ehrenburg and R. T. Watson, *Trans. A.I.M.M.E. Geoph. Prosp.*, 1932, 422–442; G. F. Tagg, Practical Investigation of the Earth-Resistivity Method of Geophysical Prospecting, *Proc. Phys. Soc.*, 1931, Vol. 43, No. 238.

[36] J. Koenigsberger, *Zeitschr. f. Geophys.*, 1930, Vol. 6, No. 2, 71–73; Broughton Edge, "Geophysical Prospecting," 1931, pp. 268–274; H. Lundberg and T. Zuschlag, *Trans. A.I.M.M.E. Geoph. Prosp.*, 1932, 47–62.

[37] J. N. Hummel, *Zeitschr. f. Geophys.*, 1931, Vol. 7, No. 5–6.

[38] K. Sundberg, *Bull. Amer. Assoc. Petr. Geol.*, 1930, **14**, 1145–1163.

[39] T. Dickman, *Gerl. Beitr. f. Geoph. Erganz.-heft. f. Angew. Geoph.*, 1931, Vol. 1, No. 3.

Interesting results have been obtained by studying the deformation of the normal field between two electrodes in presence of good or bad conductors in the ground, such as salt water horizons or salt domes.

Besides electrical prospecting from the surface, an interesting development is the measuring of different resistivities of beds by lowering electrodes in wells. This method is now proved, and used for obtaining reliable correlation data.[40]

Apart from the methods already discussed, no new progress was reported. Investigations with radio-active methods have been unsuccessful, though faults and fissures at shallow depth may sometimes be indicated by increased emanation,[41] but experiments on known salt domes in Germany and in the U.S.A. have given no reliable results.[42] In the first place the irregular oscillations of the ionisation were of the same order as the maximum variation, while in the latter area the emanation showed a relation to the heavy mineral content of the ground.[43]

Although some of the statements regarding the success of electrical methods have to be carefully scrutinised before accepting their claim, one has to admit that developments are progressing rapidly. The depth limit within the past years has been extended from 150 to 1500 ft., and the sensitivity of the instrument has greatly increased.

The ultimate aim of geophysical prospecting methods should be the direct locating of oil. It would seem that gravity, earth-magnetic, seismic refraction and electrical methods based on resistivity differences have little chance of achieving this purpose. The scope of these methods may be further handicapped in the future by the increasing depth of the oil horizons exploited. It is not impossible that new methods will be developed to fulfil the new requirements. New developments may be expected from new discoveries in physics, from new electrical methods other than those based on resistivities, and from reflections detected from the surface of liquids and gas by means of directional beams of energy.

The use of geophysics is now generally adopted, and in the future there will be an increasing need for the use of geophysical methods in oil prospecting and oil production.

---

[40] Parfenov, Melikian and Nikitine, "A New Technique in Geological Exploration," Paris, 1932.

[41] F. Mueller, *Zeitschr. f. Geoph.*, 1931, Vol. 7, No. 5–6, 241–247.

[42] F. Breyer, *Gerl. Beitr. f. Geoph. Erganz-heft. f. Angew. Geoph.*, 1931, Vol. 1, No. 4, 373–419.

[43] R. W. Clark and H. G. Botset, *Bull. Amer. Assoc. Petr. Geol.*, 1932, **16**, 1349–1356; *J. Inst. Petr. Techn.*, 1933, **19**, 81A.

Field Technology.

Edited by B. J. Ellis (Member).

DRILLING.

Rotary Drilling.

By Robert Harcus, A.M.I.Min.E. (Member).

The developments of drilling apparatus and technique during 1932 were mainly in the direction of improved control. Intensive study continued of the factors affecting drilling-bit action, and as a result there was more general recognition of the relative effects of speed, feed, torque and bit-weight in the drilling of "good-hole." Instruments came increasingly into use for reliable indication and continuous recording, not only of the foregoing variables, but also of pump pressure; while some progress was made towards reliable indications and records of pump output or fluid velocity.

Aided by the indications of these instruments, operators have been able to adjust drilling methods more exactly to the requirements of particular formations and have thus been able to realise higher drilling speeds and at the same time to reduce deviation. The cost per foot drilled has been reduced because more rapid penetration is possible. Costly fishing jobs, as result of pipe fatigue, consequent on varying torque, have become fewer in number. Decrease in wear and tear on prime movers and drilling machinery has taken place as a result of the flattening out of peak demands for power.

Speed indication was provided by indicators and recorders connected to table or draw-work shafts. Indication of torque or twisting effort was obtained on a steam-powered rig by indicating and recording gauges connected to the engine manifold which show the mean effective pressure in the cylinders. On electrically-operated rigs, torque was indicated by watt meters. The standard weight indicator was universally known; but a more accurate, if more expensive device, came to the front, employing an hydraulic cylinder carried between the travelling block and the rotary swivel. This device was found to afford a direct reading unaffected by friction or by temperature changes. The hydraulic table in itself offers means for accurate indication of weight upon the bit, and recent designs incorporated devices to that end.

The desiderata in the drilling of straight hole being established as close control of torque and bit-pressure, it was recognised that hand-feed by the operator, necessarily dependent upon the limitations of brake equipment and the skill of the individual, was unsatisfactory. The design of rotary table in which reciprocating motion is obtained by hydraulic means, offered at once the possibility

of delicate regulation of feed by simple manipulation of a valve, and the convenience of a direct measure of the weight on the drilling bit, as a function of the hydraulic pressure required to support the column of drill pipe.

Other devices intended to give automatic control of rate of feed and bit-pressure have been found satisfactory in practical use. The value of such automatic control equipment obviously depends largely on the extent to which its controlled action can be adjusted to suit particular conditions; earlier types of automatic control, employing differential gears and therefore functioning mainly as constant-torque regulators, were less satisfactory in this respect than the more recent designs, which proved their ability to maintain, whether the driving power was steam or electricity, constant feeds and bit-pressures within close margins of settings which could be determined by the operator. An important advantage of such designs lay in the possibility of immediate disconnection of the automatic features, leaving the gear available for manual regulation in emergencies.

Experience has shown that crooked holes could best be avoided by keeping the drill pipe in tension and providing the bit-pressure necessary by heavy drill collars. Long drill collars, of the largest practicable diameter, leaving only sufficient clearance for fishing, came into general use; while high rotational speeds, sharp hard-faced bits dressed true to gauge, and adequate mud-circulation, directed as close as possible to the bottom of the hole, were all found to be of assistance. In connection with the dressing of bits, it was found desirable to leave sufficient clearance above the cutting face to allow of a return to the vertical if the bit were forced out of line by some local obstruction.

Pilot bits have been used when reducing the diameter of hole for coring, etc. Reamers, used singly or in tandem, have been found useful in maintaining straight hole, although it has also been proved that they tend to increase deviation if it has once started.

In the straightening of crooked hole, various methods have been put to test, depending in most cases on the principle of reducing bit-pressure to a minimum in order that gravity might lead the bit to the lower side of the hole. Multiple-wing bits and rock-bits without reamers were generally employed in order to obtain shoulders from which straight drilling could be resumed. The practice of cementing back to a reasonably straight portion of the hole has been tried, but has commonly proved unsuccessful; the cement being almost invariably softer than the formation, and the bit, as a result, returning to the crooked hole. Oriented whipstocks have been used, but to a very limited extent, because

of the difficulty in correct positioning. Coring with a small diameter cutter head, followed by reaming with a fishtail bit has sometimes been found to reduce deviation. Among the most recent methods of starting a shoulder, the use of an expanding reamer or wall scraper met with notable success. Scrapers of this type will underream or enlarge a cavity on which a full gauge bit can start a new hole. It has been found advantageous to employ short, stumpy fishtails without reaming edges to hug the shoulder created by the wall scraper.

The control of high formation pressures, both by mud-weight and by drilling under pressure, have received considerable attention. In the method of control by mud-weight, which consists primarily in adjusting the specific gravity of the mud fluid in circulation so that the weight of the mud-column may create the required pressure on the walls of the hole, it was found, in some cases, necessary to work to limits as close as plus or minus 2 lb. per cu. ft. owing to the high porosity of strata and the impossibility of building up a pressure-resisting mud sheath on the walls of the hole. Chemically treated muds of high cost were found essential and, despite their use and the aid of blow-out preventers, great difficulty was experienced in maintaining continuous control. In an attempt to find a possibly cheaper and safer method of control, pressure drilling, employing light mud and relying on externally-applied pressure for establishment of the desired condition of balance, has been tried to a limited extent. This method necessitates packing off between drill pipe and casing so that pressure in addition to that of the mud-weight may be held on the formation, this additional pressure being maintained by means of adjustable flow beans on the mud outlet from the casing. Pressure is continuously maintained, and once imposed must not be released until high-pressure zones have been drilled through and shut off behind a string of casing or conditions otherwise indicate that pressure control is no longer necessary. Maintenance of pressure necessitates the carrying out of all routine operations under pressure. Rotation is carried out through suitable packing heads by means of flush-joint drill pipe. Drill pipe is let out and pulled in the hole with snubbing devices. Casing is snubbed in through control heads and finally cemented under pressure. To avoid the use of beans circulation in a closed circuit has been tried, but the problem of the efficient separation of cuttings from circulating fluid has not yet been solved. Work done in 1932 showed the most serious drawback of this pressure-control method to be the greatly increased time occupied in running drill pipe into and out of the hole and the extreme difficulties encountered in any fishing operations. Reduction in snubbing in and out time should take place as result of recently introduced hydraulic

snubbers, and equipment is being developed to locate the position of a break in the drill pipe and to simplify fishing.

Steel derricks came more in general use. Deeper drilling, longer strings of large-size drill pipe, heavier strings of casing and heavier equipment necessitated the use of taller, stronger and heavier derricks. Hoisting power and speeds have been increased with corresponding advance in derrick height from 122 to 136 ft., 164 ft. and, in exceptional cases, 175 ft. The ratio between increase in height and weight has not been directly proportional due to the use of steels of higher tensile strength. Capacities have also been increased without any material increase in weight. The 8 ft. sections of wooden derricks have been replaced by 7 ft. and 6 ft. panels. The use of 136 ft. in preference to 122 ft. derricks was necessitated by increased length of hoisting tackle. The 136 ft. derrick has 100 sq. ft. more working space on the floor and increased area at the fourble board. Increased area on floor and fourble board has become of importance on deep holes owing to the amount of large size drill pipe to be racked. Considerable attention has been given to safety devices such as ladders with offsets at platforms, railings and toe boards around the fourble board and crowsnest. The use of steel-framed engine and pump houses has increased.

The design of cellars and derrick and rig foundations has undergone considerable change. The open type of cellar met with general approval, and it became regular practice to raise the derrick floor some 4 ft. above the road level and to maintain 12 ft. clear depth of cellar below. In this construction the forming of corner piers, Samson post pier and retaining walls proceeds simultaneously, while particular attention is usually given to the supporting of the rotary table, extensive use being made of steel joists.

There was a distinct increase in the use of fabricated steel under-structures and tendency to eliminate cable tool-ends. The advantages of steel under-structure are long life, high salvage value and maximum clearance in the cellar. Auxiliary hoisting equipment, consisting of calf wheel, obsolete draw-works or heavy production hoists operated by obsolete size and type twin-engines have been used in increasing numbers to replace the cable tool-end. The most usual location for this auxiliary hoisting equipment was opposite to the draw-works, but that arrangement has not yet become universal. Modern construction equipment for excavating foundations, mud pits, cellars, roads, etc., has been largely used to cheapen rig building. Trucks with portable cranes and clam-shell buckets, power-operated concrete mixers and road-grading machinery have all been brought into service.

Although one new type of gear-driven draw-works made its appearance during the year, the chain-driven type remained in

general use, further increase in size and strength and improvements in details being made. For drilling to depths beyond 5000 ft., the four-speed jack shaft type of draw-works was commonly used. The general trend of development can be judged from the following details of four popular types :—

	A.	B.	C.	D.
Drum shaft	7½″	7½″	7½″	9″
Line shaft	7″	7½″	7½″	9″
Jack shaft	—	7½″	7½″	9″
Drum diameter ..	18″	26″	25″	26″
Drum spooling ..	30½″	35″	34″	46″
Brake rim	46″× 10″	46″× 10″	54″× 9½″	54″× 10″
Brake lining	1″× 10″	1″× 10″	1½″× 9½″	1″× 10″
Steel posts	10″× 10″	10″× 10″	10″× 10″	12″× 12″
Speeds	Three	Four	Four	Four
Posts	Three	Two	Two	Two
Weight	17,465 lb.	22,125 lb.	24,665 lb.	36,000 lb.

A = Ideal No. 7½ RB. C = Emsco H 54.
B = Ideal 34–26 Type " B." D = Ideal 34–9–S.

Line and jack shafts have been increased in diameter. Manganese sprockets are in general use. Roller bearings have replaced bronze bushings. Larger drums of steel construction with grooved barrels have been fitted to lessen the wear on wire lines. Drums have been equipped with forged-steel brake rims and in a number of makes are provided with water cooling arrangements. Brake mechanisms have been redesigned to improve efficiency and eliminate kick back.

Two-speed geared tables have been developed to permit selective speeds for coring operations where electric motors or internal combustion engines are employed as prime movers. Tables are now completely enclosed and provided with forced lubrication for pinion bearings and oil bath for main bearings.

At the greater drilling depths the high loads caused considerable trouble with swivel bearings, and the general demand resulted in the production of swivels having a safe load capacity of 300,000 lb.

The design of blocks was notably affected by the further study of wire-line service which had emphasised the desirability of employing large diameter sheaves. Travelling blocks having sheaves 42 in. dia., of manganese or other alloy steel, running on 8¾ in. dia. centre pins equipped with force-lubricated roller bearings, came into use. Both in travelling and crown blocks the number of sheaves was increased to meet the additional load imposed by longer and heavier strings of drill pipe : in the case of crown blocks this addition further encouraged the development of the double-deck design as the only practicable means of using large-diameter sheaves without increasing the size of the water-table opening. Crown blocks have been developed with a safe load capacity of

500 tons, these blocks being built on a framework of 24-in. H beams, and weighing nearly 5 tons complete.

The introduction, two or three years ago, of chain made from alloy steel has been carried further to meet the increasing requirements of deeper drilling. Side bars and pins have been made heavier and a new type of roller made from heat-treated alloy steel strip has been incorporated in one popular make of chain.

Drill pipe preceded casing in the use of A.P.I. grade D material in its manufacture permitting the pipe to meet more severe drilling conditions at increased depth. The improved quality of drill pipe, together with straight-hole drilling practice, has been instrumental in reducing twist-offs.

It has become general practice to employ one stand of drill collar made up of individual 30 to 40 ft. lengths. The use of 10 in. dia. by 40 ft. long drill-collars and 8 in. drill pipe was favoured for large holes, while 12¼ in. dia. drill collars with 10¾ in. o.d. drill pipe have been used successfully.

While rubber and fabric hoses remained in common use for normal drilling conditions, steel hose—which has been operated successfully at 5200 lb. per sq. in.—was increasingly employed for severe service and even for normal conditions of drilling.

Roller-bearing bushings have met with general approval in the field. Friction is reduced, weight indicators register more accurately and because binding is decreased, a constant weight can be more easily maintained on bottom.

Moulded brake-linings have been tried, and appear to show promise.

Vibrating screens for the removal of cuttings from the drilling mud have come more into use and have resulted in a better quality of mud, less replacement of mud, saving in swivel and pump parts and reduction of shut down time. The capital cost has been found more than justified as in many cases drilling time has been reduced by as much as 20 per cent. Major upkeep cost is represented by screen cloths which have a life of 400 to 500 working hours. The size of screen most commonly in use is 6 ft. by 4 ft. It will handle about 800 barrels per hour which is ample for normal requirements. Capacity is reduced by increase in viscosity of mud and where viscous mud is in use 8 ft. by 4 ft. screens have been installed. There are several makes on the market each varying in the method of producing vibration. The majority produce vibrations at the rate of 1500 per minute while some go as high as 3600. The pitch is usually adjustable to provide for variable mud conditions.

Tests have shown that a very considerable amount of circulating pressure is absorbed in pumping mud through the restricted passages in Kelly and tool joints. The loss may amount to 4 lb. per sq. in.

per tool joint and in consequence serious attention has recently been devoted to tool joint design. Tool joints on the principle of venturi tube to yield a streamline effect have been shown to reduce pressure and cutting out of tool joints experienced on deep wells as result of high-pump pressure. The "full hole" tool joint is increasing in demand.

Advances in fishtail bit design include type of steel, minor changes in shape, application of hard facing and insert material to cutting and reaming edges, improvements in method of applying hard surfacing, heat treatment, and normalising after hard facing. There has been a tendency to employ alloy-steel of air-hardening properties so that normalising treatment imparts properties better suited for surfacing. In this way attempts have been made to reduce costs by elimination of heat treatment. In the hope of producing smoother bit action, increasing footage, and reducing drill-pipe failures, multiple-wing and other special types of bits have largely been employed in replacement of fish-tail bits. Of these special types, it has been claimed that multiple wing and serrated tooth bits provide additional bottom-cutting surface and increased guiding length of the non-cutting edge. Rotation is, therefore, more uniform with increased life due to increased surface available for hard facing. Removable rolling or turning cutter-bits have been found suitable for dealing with rapidly alternating formations in which sandy shale predominates. Bits of this type appear to be particularly adaptable to formations of medium hardness and where the characteristics of the formation is toughness rather than hardness.

Although core barrels have advanced little in essential design, the increased adoption of continuous coring for study of important horizons and the provision of weight and torque indicators led, during the period under review, to improved and established technique, resulting in improved core recovery. In general it was found that the larger sizes of core-barrel gave better recovery, and core-barrels to drill the full diameter of the hole came into common use. Core-barrels showed improvements in detail through the adoption of high-grade heat treated material, hard inserts, and rigid gauging of parts such as cutter-heads. Periodical heat-treatment has been practised, to relieve strains set up in working; and breakages have been reduced thereby. Barrels of length up to 45 ft. have come into use; while to meet the increased weight of the longer cores, double catchers have been employed in the cutter-head with secondary catchers between sections of the inner barrel. Among other types of cutter-heads which came into use, mention may be made of a head having two sets of blades arranged to make simultaneous contact with the bottom of the hole, a

three-bladed head, and a design in which the catcher closes automatically when the barrel is raised from the bottom.

Safety joints have been increasingly employed in the drilling string, as a regular practice and not only for deep or difficult wells. The design of such joints has been improved, the flush-hole diameter being made equal to the bore of the drill-collars, to facilitate the use of certain types of inclinometer. The release-factor has been increased, and packing arrangements have been improved to withstand higher pump pressures.

Recent designs have avoided the necessity of rotating hydraulically-operated jars, set and reset by the weight of the string, tripped by pump pressure and capable of making three or four blows a minute of controllable strength, have been used; jars of mechanical type have been developed to make from 5 to 10 blows per minute of controllable strength while allowing of continuous circulation; and jarring-down jars, designed for use in conjunction with perforators, have also been put into service.

Cutters have become available for cutting inside or outside of drill-pipe and casing, the tools being arranged to run on tubing, drill-pipe or casing accordingly to requirements. Various methods have been employed for effecting the feed-motion, including lead-screws and hydraulic pressure, but in most cases provision has been made for indicating to the operator when the cutting operation is finished.

Rotary Drilling Mud. By ALEXANDER REID (Associate Member).

THE critical position of the oil industry in 1932 naturally led operators to consideration of sub-surface economies. Since mud is one of the costly items in drilling expenditure, considerable study has been made of possible economies in this direction. At the same time much accurate research has been done, chiefly by American chemists. The net result has been a considerable increase in the literature on the subject, with a corresponding improvement in mud technique generally.

In the mixing and "doctoring" of muds the funnel mixer has almost entirely supplanted the old-fashioned paddle type. Mud is now mixed and pumped down the well in what is almost one operation, or prepared under skilled supervision at a central mud plant, which may cater successfully for over a hundred wells.

Central mud plants have become more numerous than ever, and their scope correspondingly wider. Some plants now undertake the reclamation of drilling mud (by de-sanding, de-gassing, etc.), recovery of expensive weight materials, and the preparation of special muds to any given prescription.

The vibrating screen, as a means of de-sanding mud, has grown in popularity, chiefly owing to its simplicity, comparative cheapness, and improvement in design. Settling and centrifugal methods are still practised with success in some parts of the United States.

Both chemical and mechanical methods have been practised in de-gassing. The former relies on the addition of alkali to the mud and subsequent violent agitation by passing through a mixer. Mechanical means include the passage of the "gassy" mud over a tower, jetting of the gas-cut fluid against a solid surface, and the application of slight vacuum, together with mixing and heating, in a suitable container. The latter method is the subject of a recent patent, and maximum efficiency is claimed; details of practical application on a large scale are lacking and there is some doubt of its success.

The near approach of pressure drilling has focussed attention more and more on the preparation of suitable muds, rather than on the making of muds of high specific gravity. Several good weighting materials are on the market, and are claimed to increase the colloidality of the mud as well as weight it.

Laboratory work has been largely directed towards the study of colloidality, while the accurate measurement of viscosity, and the preparation of muds to seal porous sands or to enable wells to be drilled in by rotory without damage to the producing face, are the subject of many published researches.

It is agreed that colloidality is the most important consideration in almost all drilling muds, and its measurement has occupied a good deal of attention. No method so far published stands the closest inspection. Estimation by the absorption of dyes (such as malachite green or methylene blue) has found favour in certain areas. Some workers have attempted to relate the properties of viscosity and colloidality; this line of research is distinctly promising.

Consistency of mud fluid (which is essentially related to colloidality and viscosity) has been found to have an important bearing on the plastering of the walls of the hole. The thickness of filter cake deposited on the walls has been shown, by Crump and Cannon in the U.S.A., to be independent of the applied pressure, and dependent on the quality of the mud fluid, more especially on its colloidality. Excess sand is said to increase the thickness of the filter cake so much that it may be responsible for the familiar phenomenon of "shrinking hole." The cake formed by a mud of high colloid content may be only 1/16 in. thick, yet it will effectively resist the further infiltration of water into the hole, withstand considerable pressure, and remain almost unaffected by the erosive effect of the fluid continually passing over its face. The

importance of these results in the preparation of muds for drilling by rotary, and in the sealing of so-called " porous formations," cannot be gainsaid. Incidentally the above investigators claim that " lost circulation " is entirely due to the presence underground of fissures and cavities, and not to sands of high porosity. This is, at least, open to doubt.

Although the study of muds has been prosecuted for many years the methods of measurement have not shown progress in accuracy commensurate with the growing importance of the material. Most especially is this true of viscosity measurement. The number of different viscometers must be legion, yet none gives results of irreproachable accuracy. It is heartening to record that several workers during the past year have given attention to this matter and that the development of a really reliable and simple viscometer seems to be in sight.

Among other lines of research, attention has been given to the study of " heaving shale." Few more distressing problems confront the driller, and the number of holes abandoned due to this cause steadily increases. The advent of pressure drilling will do much to help and the problem will, most probably, be overcome by a combination of externally applied pressure and suitable mud. Again the colloidality of the mud assumes considerable importance. Some measure of success has been attained in the overcoming of " heaving shale " by the addition of sodium tannate to the drilling fluid, but the action of the chemical is not fully understood. Here is a fruitful line of research.

A number of new preparations to improve the quality of mud have been put forward during the year, and some of the older mixtures have maintained their popularity. For increasing the colloidality of the fluid " Aquagel " remains a favourite ; many instances are cited of its successful use. In securing viscosity reductions, soda ash, water-glass, sodium tannate, and caustic soda have found most use.

Many " fissure-sealing compounds " are marketed, relying on various principles. One company has had some success with mixtures of low " yield value " but high viscosity ; these are easily pumped, but may be so made that, once in the crevice they gel and " set," efficiently sealing the apertures.

Improvement is shown in the application of all these agents, thanks to a more complete knowledge of their possibilities and limitations. These is still room for improvement in mud technique amongst operators, however, and it is disappointing to note that there is often much confusion of such simple concepts as " weight " and " viscosity." On the other hand it must be recorded that

there is now more uniformity in the types of mud used for different purposes than there was even a year ago. Mud technique develops slowly, but surely.

Water Location during Drilling. By ALEXANDER REID (Associate Member).

ALTHOUGH the existence of small water sands may be obscured by highly-efficient mud-circulation, there is as a rule sufficient infiltration of water from the sands to effect some change in the mud-quality. Reliance has generally been placed on such indications, and wells have been equipped with mud-weight indicators placed at the discharge from well to ditch and sometimes also near the suction. On this system, any notable reduction in specific gravity of the mud has been taken as evidence of dilution by water, and consequently of the presence of a water sand. The method necessarily depends upon homogeneity of the mud and sensitivity of the mud-weight indicator; neither of which can be ensured; misleading indications are therefore possible and even common; instances have also occurred, when circulating mud under relatively high pressure, of increases in the specific gravity of the mud, owing to penetration of sands by water from the mud.

The shortcomings of the mud-weight system have led to the use of salinity tests. It has been argued that since most water-sands in oil country yield more or less saline water, any notable increase in salinity of the mud would indicate the penetration of a water sand. Strikingly useful results have been obtained in some instances, although the method is inherently not highly sensitive. Misleading indications may occur when drilling through salt-bearing strata, salts from which may enter directly into solution in the mud.

Proposals have been made to record continuously the hydrogen-ion concentration (pH value) of the mud in order to indicate changes in mud quality. This method is not known to have been put into practice.

It has been observed that certain colloids, sometimes present in drilling mud, coagulate in the presence of salt. Indications of infiltration of saline water have been obtained from the presence of coagulated material in the mud returns.

Much attention has been given by certain operators to the testing of freshly extracted cores for oil and/or water content. Oil content in such cores has often proved to be a guide to the potential productivity of the relative sand; but indications of water sands have proved unreliable. The method may be carried further, however, by the use of mud of high colloidality (not necessarily of

high viscosity) which, as experiment has shown, is capable of forming remarkably firm and impervious coatings on the walls of the drilled hole. Cores obtained while circulating mud of this special character may be expected to be more representative of the strata from which they are drawn.

Attempts have been made to treat cores with oil-soluble and water-soluble dyes, following the idea well known and widely practised in bacteriology. Some success has been met with indications of oil, but indications of water have usually been inconclusive.

Electrical systems of water location, depending as a rule upon variations in conductivity, have met with fair success and are being developed further.

Cable Tool Drilling.

This method of drilling continued in use for shallow wells in many areas, for a few deep wells chiefly in the Eastern area in the U.S.A. and for the completion of rotary-drilled wells where formation pressures were low.

The increased depth of drilling necessitated heavier rigs and a change from the rope-driven bull wheel to a separately powered chain-driven bull wheel very much on the lines of a rotary draw-works, but otherwise both in principle and in detail the method and equipment remained unchanged.

Well Equipment. By W. Wade, A.M.I.Mech.E. (Member).

The reduction in drilling activities during the year has led to investigation into methods of effecting economies in the expensive item of casing and has also given time for further attention to refinements in casing for use in deep test wells which are increasing in number.

Casing stocks on the fields have been maintained at a minimum and the reconditioning of casing from exhausted wells has been employed to a greater extent. In view of possible mechanical hazards and the large investment involved in re-running casing in deep wells, gauging and drift tests have been made on casing pulled from wells to determine the damage done to a once-used string of A.P.I. Grade "D" casing. These tests have shown that 30 per cent. of the casing in three strings had to be rejected because of damaged threads and two to three joints in each string were rejected because the drift mandrel failed to pass, indicating an out-of-round condition which would not only materially lower the safety factor of the casing against collapse, but would also offer hazards of sticking bits, small casing and cementing plugs.

To effect economies consideration has been given to the following factors :—

1. Quantity of casing.
   (*a*) Use of less casing in the protection of the hole and producing zones to be cased off.
   (*b*) Use of combination oil and water strings.
   (*c*) Use of combination liners.
2. Size of casing.
   (*a*) Improved drilling technique, permitting decreased clearances.
   (*b*) Possible increased use of flush joint and/or welded casing.
   (*c*) Wider use of under-reamers.
3. Combination of weights of casing.
4. Combination of grades of casing.
5. Standardisation of casing sizes.

Considerable attention has been given to obtaining greater clearances between the strings and has been effected by using a larger size of surface hole and the extension of the length of each sub-surface string involving the use of high tensile pipe and flush-joint pipe.

Grade " D " casing has been employed to a greater extent and investigations have been carried out on steels having a minimum tensile strength of 100,000 lb. per sq. in. The latter has presented difficulties in machining, but it is expected that these will be overcome without resource to heat treatment of the pipe after machining operations have been carried out.

The A.P.I. Specification has been amended to include flattening tests for Grade " D " casing, such tests being hitherto considered unnecessary for seamless material which at that time had only reached the Grade " C " stage.

Externally and internally flush-joint casing has received a certain amount of consideration and although it has not been used to a large extent several different styles of flush-joints have been evolved. With this form of joint, it is not, however, possible to obtain a tensile strength greater than two-thirds the strength of the body of the pipe as compared with the strength of the net area of metal at the root of the first perfect thread for collared casing. In the case of collared casing there has been an increased use of long couplings and longer thread on the pipe which type of joint is stronger than that provided by the shorter coupling.

Experiments have been carried out to determine the effect of external pressure on casing having a low ratio of wall thickness

to outside diameter of the pipe, and results obtained have shown that resistance to external pressure is a problem of crushing by cross-breaking and it is not the tensile strength, but the modulus of elasticity which is the deciding factor. This means that where the t/D value is 0·032 and under, casings made from material having a higher yield point than A.P.I. Grade "C" will possess no greater resistance to failure by external pressure than casings made from Grade "C" material; therefore, in these cases the only means by which greater resistance can be secured is to increase the wall thickness.

A step towards international standardisation has been made by the completion of a draft British Standard Specification for Oil-Well Tubular Goods. Subject to approval by the Technical Committee of the British Standards Institution for publication, this specification will give a standard for casing, drill-pipe and tubing which will be interchangeable with similar material made to the relative A.P.I. specification.

New types of casing-head of forged-steel construction for packing off between casing strings have been placed on the market as replacements for the usual form of cast-steel casing-head flanges used above the landing flange. The design embodies a stuffing box with split seat and gland and slips for supporting the casing.

To meet the demands for higher well pressures, heavier valves and fittings made from forged and/or nickel-chrome steel, for well-cellar equipment, have been used and a test pressure of 6000 lb. per sq. in. is no longer considered an abnormal or unnecessary high rating.

Cement. By A. REID (Associate Member).

DEVELOPMENT in oil-well cements has, to some extent, kept pace with improvements in cementing technique. The year has seen remarkable cement jobs successfully accomplished at depths over 9000 ft. and only first-class cements could answer to such exacting demands as have been recently made on them.

Attention has possibly been unduly concentrated on the production of cements to meet these extreme conditions, and there seems room for more research towards the establishment of grades of cement to meet less exacting but still important requirements. Much has been published on the practice of cementing, but little upon the properties of cements and the factors which influence setting and hardening in wells.

Specifications have varied widely from area to area, and there have been instances of the use of a single grade of cement for all

classes of work. In general, however, three broad classes of cement have been employed :—

(*a*) Special deep-well cements.

(*b*) Cements manufactured for oil-well use, not necessarily for deep wells.

(*c*) Cements with no special properties in relation to oil-well use.

Practical considerations have shown slow-setting as an important characteristic, to offset the high temperatures which are frequently encountered in deep wells and which are known to accelerate the setting process. In some instances slow setting has been combined with rapid hardening properties. Manufacturing methods have included relatively coarse grinding of the cement-clinker, and adjustments of composition such as an increase in the proportion of iron in the mix. Cements have been marketted containing as much as 5 per cent. of iron. In this connection it is interesting to note that " Erz " cement which is made from siliceous limestone and iron ore, can be mixed with plaster and exposed to concentrated saline solutions under pressures up to 1500 lb. per sq. in. without showing expansion or contraction. In similar circumstances ordinary Portland Cement would be destroyed in a few days. No one so far appears to have considered " Erz " cement (or modifications) for oil-well use, but investigation might be fruitful.

Other controlling factors in the mix are the percentages of lime and of calcium sulphate : it has been found that high-limed and well-burned cements are usually slow-setting, and that the percentage of sulphuric anhydride may be larger than the 2 per cent. or 3 per cent. usually specified.

Very little has emerged in the direction of standardisation : the greatest demand has, however, been for a cement which, gauged with 40 per cent. water, would take its initial set in 3 to 4 hours.

Construction grades of cement have been used in wells that require large volumes of cement ; the cheaper grade being used to form the first part of the grout, and followed by special cement. The practice appears to be sound and may increase in popularity.

It has become a common practice to circulate the coldest attainable mud fluid before cementing and to use the coldest attainable water for mixing the cement. Results have been encouraging and the practice may extend. Conversely it has been proposed to prepare cements with a view to employment under relatively high temperatures.

Well Surveying. By P. EVANS, B.A., F.G.S. (Associate Member.)

ALTHOUGH it has long been known that the small diameter bore-holes put down in search of gold, coal, etc., were often appreciably crooked, it is only in recent years that much attention has been paid to the deviation of oil-wells. When most of the drilling was done by the percussion system, there was comparatively little chance of wells going badly crooked unknown to the driller, as any sharp kink was shown by the bits and under-reamer cutters, by the motion of the tools, and by difficulty in getting the casing down; nevertheless, it is probable that the general tendency was to assume a greater degree of straightness than was justifiable. When rotary drilling came more into use, the driller still continued to assume that if drilling went on steadily without undue wear of tool-joints, and if the pipe turned moderately easily in the hole then the well was approximately straight. It was thought that a really crooked hole was bound to be indicated by the wear of the bit and drill-pipe and by the way in which the hole drilled. Very rarely was reliance placed on instrumental aids in detecting crooked holes, and wells were not surveyed, as although devices for well surveying had long been in use in diamond drilling, none of these was specially adapted to oilfield requirements.

A great change came about when it was discovered (independently in Assam and America) that wells could go very crooked without the driller having any knowledge that they were other than straight. This led to the introduction of instruments designed to measure the deviation of wells and during the past two or three years much progress has been made in their development.

Inclinometers, as well-surveying instruments are usually called, are most useful if they can be run in uncased holes, and it is an advantage if they can be run either on sand-line or drill-pipe, *i.e.*, without any special insulated electric operating cable to the surface. The measurement of the *amount* of deviation is much simpler than the determination of *direction*, but recent progress has included improvements in both directional and non-directional inclinometers.

Well surveys fall into three classes :—

(i) determination of amount of deviation by a non-directional inclinometer;

(ii) determination of amount and direction of deviation, using oriented drill-pipe and a non-directional inclinometer;

(iii) survey with a directional inclinometer.

The non-directional inclinometer is most useful in detecting the first tendencies to an increase in deviation and in ensuring that

the departure from verticality does not exceed the permitted tolerance. The directional surveys are usually made over a large range of hole. It is therefore desirable for non-directional inclinometers to be simple single-reading instruments and for directional inclinometers to be able to take a number of readings.

A hole cannot easily be kept straight unless tendencies to deviations are corrected at a very early stage, and present practice, wherever drilling straight holes is a matter of difficulty, is to take readings at very frequent intervals. Time is saved if the inclinometer can be dropped down the drill-pipe in a "go-devil" or "bomb," but difficulty is caused by possible non-alignment of the bomb, the drill pipe and the axis of the hole and by the very small diameter available inside the "bomb." The acid bottle has been used for this purpose, but has proved unreliable, owing to capillary effects and the prolongation of the action of the hydrofluoric acid during pulling out. Better results have been obtained by the plumb-bob "drift indicators." In these instruments a plumb-bob is depressed on to a disc marked with concentric circles. In the "Elliot" instrument, which is of the "go-devil" type, the pumb-bob is depressed by the action of the mud pumps. In the "Bull's Eye" type, which has been extensively used with fairly good results, the "go-devil" is followed by a mandril, and this, on striking the head of the drift indicator, releases the plumb-bob, The "Hydril" is run in with the drill pipe and is operated by dropping a steel ball and starting up the mud pumps. The Shaffer instrument is intended as a warning during drilling, as it is so arranged that if, when a reading is taken, the deviation exceeds a certain pre-arranged figure, the mud passage is restricted and the pumps register an increase in pressure.

Despite the speed of operation of the go-devil types on non-directional inclinometer, they are not capable of the accuracy of the larger inclinometers and where deviation troubles are acute it is desirable to make use of other instruments either for occasional checks or at very frequent intervals. For this work the large acid-bottle run on a sand line is useful, but the time taken for etching is an undesirable feature and alternative methods, in which there is much less waiting, are of service. Amongst these are several single-reading inclinometers of the spirit level or plumb-bob types, operated by clockwork and recording photographically or mechanically, and a few, such as the Clinograph, in which coloured ink marks a horizontal line on a paper cylinder.

A large number of wells have been surveyed by some method dependent on drill-pipe orientation, but although this gives fairly good results in shallow wells which have few changes in the direction of deviation, it is doubtful how far this method is reliable

in other circumstances, and the recent tendency has been to utilise a true directional inclinometer based on either a magnetic or gyroscopic compass combined with a spirit level or plumb-bob. Where readings are to be taken in uncased hole the magnetic compass is most useful and several inclinometers have been devised to work independently of surface control. On account of their simplicity, instruments taking one reading have a fairly wide sphere of usefulness and the most ingenious and simplest of these makes use of surface-tension effects modifying the etch produced by hydrofluoric acid in which a magnet is floating. As, however directional readings are most often required over a long range of hole, most of the recent directional inclinometers are multiple-reading instruments recording photographically or by a mark on paper. The magnetic compass lends itself to this and several magnetic inclinometers have quite recently been brought into use. The gyro-compass is very much more complicated, but it has been used successfully in the Surwel instrument, which is entirely self-contained and can be used in cased and uncased holes, and in the Martienssen inclinometer, which is operated from the surface and is restricted to cased holes.

Inclinometers which work on drill pipe or sand line are usually arranged to operate by clockwork at predetermined intervals, the depth at each time of observation being recorded by the operator. Those instruments which need an electrical connection to the surface are usually operated by closing a circuit with a surface key, the record being made in the instrument. An insulated cable is expensive and awkward to handle, and it would seem an advantage if inclinometers needing such a cable could be made to record on the surface, but no moderately simple instrument of this type has so far been described.

Allied to the determination of the direction of deviation of wells are the attempts that have been made to obtained "oriented" cores so that the direction of underground dip can be obtained. The difficulties are considerable, but in fairly hard formation, where the core has less tendency to rotating in the core barrel, a measure of success has recently been attained by the Macready instrument in which a multiple-reading clockwork-operated magnetic inclinometer is attached to the inner core barrel. In suitable formation, fair results can be obtained by an oriented chisel mark on the top of the prospective core, but this method, at best, is slow.

Besides well-surveying in the sense of mensuration, there are possible numerous measurements of temperature, rock pressure and electrical properties; these last are most useful when determined before casing is set.

Within the past two or three years advances have been made in the investigation of the electrical properties of uncased holes. It has been found that the resistance of beds can be estimated fairly well by comparatively simple measurements with a potentiometer connected to electrodes which are placed in a well which forms part of an earthed circuit. A close connection has been established between electrical resistance and the nature of the strata and included fluids. Small variations in other electrical properties in different parts of the hole have been found useful in supplementing the evidence from resistance, and electrical surveys on these lines now promise to give data enabling oil sands and water sands to be detected in rotary holes and so to form a very useful adjunct to coring. The name "electrical coring," applied to Messrs. Schlumberger and Leonardon, is unfortunate, as their system has nothing to do with coring.

The electrical log of a well is usually plotted to show the porosity or resistivity of the strata on the horizontal scale and the depth vertically. The result is something like a comb with very irregular teeth, and comparison of the logs of different wells may reveal a high degree of correspondence in the size, shape and disposition of the "teeth" and so enable quite detailed correlations to be made. Schlumberger's electrical survey may also be used to determine the rock pressure in water sands, and the temperature at depth, and may in time be extended to give reliable data of dip and strike of the beds drilled through.

Power.

There has been little development in steam power plant for rotary or cable tool drilling. A 14 in. by 14 in. horizontal twin-cylinder, totally enclosed steam engine has been produced and used to a limited extent and slush pumps up to 20 in. stroke were made. Boiler pressures were not increased beyond 300 lb. per sq. in. and there was a tendency not to perpetuate this high pressure but to drop to 250 or even 200 lb. per sq. in. Superheaters, used for several years past outside the U.S.A., came into use there, and, in a few areas where water supplies were difficult, condensing and heat recovery equipment was installed. The insulation of boilers and steam lines became more popular, resulting in better steam conditions at the engine, and in lower fuel and plant costs. Water softening and treating plants were more widely used. A careful and complete investigation into the steam consumption and losses on rotary drilling rigs was made early in the year under the auspices of the American Society of Mechanical Engineers, and focussed attention on the great economies that could be

obtained by adhering more closely on the oilfield to the principles that are followed in more permanent steam installations in other industries.

Trials of Diesel and Diesel electric equipments continued, direct current on the constant current-variable voltage principle proving the most suitable for the latter. Several types of multi-cylinder, high-speed Diesel engines, weighing approximately 40 lb. per h.p., in sizes of 25 h.p. and 50 h.p. per cylinder, were developed during the year, and one at least has been fully tried out on the oilfield with highly satisfactory results. The problem of a reasonably priced and efficient direct drive arrangement between internal combustion engines and the draw-works, pumps, cable tool end, etc,. was not solved.

Alternating current electrical equipment underwent considerable development, drilling motors being increased in size up to 250 h.p. or run in pairs of 100 to 125 h.p. on twin reduction gears. Contactor control geat, electrically operated *via* time lag devices, replaced to a large extent the direct hand-operated controller and brought about considerable economies in maintenance both of electrical and mechanical equipment.

Slush pump motors were also increased in size, up to 200 h.p., and experimental work, in an effort to obtain "steam engine" characteristics from an A.C. motor, was successfully concluded and the new equipment was put under field test.

PRODUCTION.

Gas Lift Methods. By L. W. Rogers.

Advancements in all production systems for mechanically producing oil and their operation have been retarded on account of the over-production from naturally flowing wells. Improvements in the gas lift system have been concerned mainly with the obtaining of higher lifting efficiencies by the more general adoption of tapered tubing strings which aim at establishing a flow velocity such that excessive friction and slippage are avoided.[1] The main advantages attendant on an efficient tubing design are that a smaller input gas/oil ratio will be required and the gas lift period can be continued economically to a lower rate of production than would otherwise be the case. A reduced formation gas/oil ratio will not be obtained by any increase in the lifting efficiency.[2]

[1] R. R. Hawkins, "Flowing Wells with small Tubing," A.I.M.E., Petroleum Division, 1932, and K. B. Nowels, "A Method of Computing Pressure Drop in the Pipe of Flowing Oil Wells, A.I.M.E., Petroleum Division, 1932.

[2] "Effects of Rate of Production and Producing Equipment upon Gas Oil Ratios," by J. T. Hayward, A.I.M.E., Petroleum Division. 1932.

For reducing the high kick off pressures required when starting up wells on gas lift, "Kick Off Units" or "Unloading Valves" have been made available. These are used at intervals in place of the ordinary tubing collars, and enable the head of liquid formed in the tubing to be lifted in sections until normal gas lift is in operation. Such units have been found particularly useful on tapered tubing strings on account of the increased head of liquid obtained with the smaller diameter tubing on bottom.

It has been found necessary to give close study to the duration of gas lifting, both as regards the lowest rate of production at which gas lift is economical *per se*, and with respect to the maximum capacity of the pumping system selected to follow the gas lift. From the latter point of view the possibly embarrassing effects of formation-gas have gradually become evident. It has been found that in wells having a high ratio of formation-gas to oil the maximum capacity of the pumping system used after gas lift is reduced and the ordinary difficulties of pumping are increased.

Intermittent gas-lift with open-ended tubing has been applied in the hope of reducing the ratio of input gas to oil during the later stages of gas lift, but has not proved generally effective. Advantages were claimed in some instances, although it is possible that at least equal results might have been achieved by continuous gas lift with improved tubing strings, or by earlier application of other pumping systems. General experience indicated that intermittent gas lift (for the successful operation of which the desiderata are a highly consolidated oil sand, a relatively small annular space between tubing and casing, and large gas volume) has its most promising field of application as an interim measure, between the cessation of continuous gas lift and the commencement of plunger or displacement pumping.

The equipment used for intermittent gas lift consisted of automatically operated input gas valves, with means for controlling them to the required time-cycle, such as are employed for surface control of displacement pumping installations.

Displacement pumping has made steady progress during the past year. Equipment has been improved and a wider range of producing conditions has been handled successfully. The real incentive to development has been to provide a method of production which would enable the whole gas lift installation to be continued in use after gas lift, and at the same time to provide for the deeper wells a system not subject to the inherent disadvantages of plunger pumps. Many displacement pump installations have been in operation at depths of over 7000 ft. for long periods without a single pulling job. The system has also proved

itself to have many advantages over plunger pumping under bad paraffin and also under severe sand conditions.

Since the mechanical efficiency of the displacement pump is inherently lower than that of the plunger pump, the former has usually been found economical only under conditions of ample supply from flowing or gas wells of high pressure gas. Where, however, compression of air or gas is necessary to produce sufficiently high pressure for operation of displacement pumps, experience has been that the plunger pump is preferable.

The most satisfactory service, on the whole, has been obtained from horizontal two-stage compressors of the direct driven type having twin power cylinders operating either on the two-stroke or the four-stroke cycle at about 250 r.p.m. In view of overloads arising during the " break-over " of wells on gas lift, or through sudden rises of intake pressure, it has been found desirable to have ample reserve capacity in the power-ends of such machines. More attention has been paid by designers to the necessity for reducing clearance-volumes, and compressors have been designed especially for use with gas, taking into view its properties under compression and expansion. Owing to the practical difficulties of reducing clearances below certain limits, long-stroke machines have been largely preferred.

In respect of size, machines rated at 100 h.p. have proved popular, but larger units have been employed. The two-stroke cycle, although usually more extravagant in fuel consumption, has retained its popularity owing to its simplicity and more even turning-moment. Power-driven compressors have been extensively used where cheap electric power is available: transmission has usually been effected by short-belt drive from electric motors of flame-proof design.

The standard arrangement of control has not developed appreciably. Gas delivered from the compressors is usually held, at constant pressure slightly in excess of that required for the highest pressure well, in a manifold from which it is led to individual wells. Regulation of delivery to each well is effected by manually operated needle valves, adjusted according to the readings of orifice meters, although automatic volume-controllers have been used in some instances. The use of recording gauges for tubing and casing pressures, and of recording orifice meters for output measurement, has become general.

Where displacement pumping has been adopted in succession to gas lift, few modifications to surface equipment have been found necessary. Accurate measurement of input and output gas has been found difficult owing to the fluctuations of flow and

pressure and, to overcome this, various adaptations of the usual metering equipment have been tried.

Orifice Meters have been greatly improved. Integrating Meters are now available, and the orifice changing devices and adjustable orifices eliminate the necessity of a by-pass round the orifice plate flanges.

Flowing Methods.

THE producing of naturally flowing wells through casing or other eductor columns of large diameter is gradually becoming less general, even when the wells are in a flush production stage. The apparent advantages coincident with the use of flow strings of reduced cross-sectional area are causing many operators voluntarily to complete their flowing wells with tubing of some kind, introduced into the wells generally before completion. The tubing is thus of service in washing a rotary-drilled well free of mud during the completion process, as well as of value in supplying a flow column of a size favourable for the most efficient utilisation of the natural forces available in the reservoir.

In several new fields in Texas, including the East Texas and Conroe fields, the use of tubing of not larger than a specified diameter is made mandatory by the State authorities. Tubing has been used in all wells in other flush fields, notably the Hobbs field of New Mexico. In the Yates field of Texas, all wells having a gas-oil ratio higher than a certain average are required to be tubed in order to reduce wastage of gas and the consequent unduly rapid dissipation of reservoir pressure.

Tubing is being used also to prolong natural flow in the later life of flowing wells, and in some cases has been used to induce flow in wells which have been produced by pumping or other artificial means for considerable periods of time.

The maintenance of natural flow in oil wells by the use of bottom-hole chokes in connection with tubing has been accomplished. In gas wells, the freezing of surface connections because of the expansion of gas through a choke at the well head has been prevented by use of a suitable choke at the bottom of the tubing. Gas wells are also kept free of water by this means.

Regulation of production rate by surface choking continues to be general practice. The effect on gas-oil ratios of restraint imposed at the well head, particularly when there is a considerable quantity of free gas in the reservoir, is generally unfavourable.

Straight tubing is the type most generally used, although certain operators claim advantages for tapered tubing, both as regards the reduction of gas wastage in flush wells and for the stimulation of natural flow in weak wells. Few data are available upon which

to base a direct comparison of straight and tapered flow columns, but information which has been obtained thus far indicates a probable slight advantage for tapered tubing. The general trend is toward smaller tubing sizes, because of more desirable flowing conditions induced therewith, and because of the reduction in investment thus accomplished.

Properly designed tubing should in most cases be run sufficiently deep into an oil well so that at least a moderate degree of actual submergence in fluid in the lower portion of the well bore, under working conditions, is accomplished, to seal off gas from possible dry gas horizons existing above the oil reservoir. The tubing should, at a given point, be of such diameter that velocities most suitable for an oil-gas mixture under the conditions of pressure and temperature there prevailing may be maintained, for a predetermined production rate. If the foregoing is strictly interpreted, an increase upward in effective cross-sectional area of the tubing is indicated to be necessary, if an approach to optimum conditions in the well bore is to be maintained.

There is a wide range of fundamental factors which might affect the flow of an oil-gas fluid from the outer circle of influence of a well to the surface, and a lack of knowledge of any one of many of these could conceivably cause a considerable variation in the results obtained. The greatest need in flow column design is for a greater number of, and more accurate, basic data.

The most striking demonstration of the use of tubing as a means of preventing gas wastage has been had in the Yates field, of Texas, during the past year. The first work toward gas conservation by this means was done in December, 1929. This and later work in that field was so successful that finally the Texas authorities ordered that all wells with a gas-oil ratio, at the allowed production rate, above the average for the field, should be tubed. There are now approximately 300 wells tubed, of the total of slightly over 400 wells in the field. The gas production has been reduced sufficiently to effect a 42 per cent. reduction in volumetric withdrawal from the reservoir. This has served to materially lessen the reservoir pressure decline.

In East Texas the tubing of all wells has not as yet been of any appreciable benefit, as regards gas conservation. There is, as far as can be determined, no free gas existing in the reservoir, under the pressures now prevailing, and probably none exists until the oil has progressed a considerable distance through the well bores toward the surface. Hence, under present conditions, no change in gas-oil ratio can be effected by any equipment in the well bore. The anticipated beneficial effects of the tubing will probably become

more apparent when the reservoir pressure has been lowered to a considerable degree.

Good results from the use of tubing in connection with the lengthening of flowing life and stimulation of flow in old wells have been obtained in California, West Texas, and in some of the old shallow sand fields in northern Oklahoma.

Producing wells are being tubed under pressure, with no loss of production, and bottom-hole chokes are being installed in the manners described by Otis[1] and Ross.[2] Only minor changes have been made in the equipment necessary for running tubing and chokes.

The study of reservoir pressures has undergone marked development in the past year, particularly in the East Texas field, the Yates field of Texas and the Hobbs field of New Mexico.

Reservoir pressures are being used to estimate flowing life; to foretell the locality and direction of water encroachment; to determine relative permeability of a reservoir in the vicinity of a given well; and to obtain an approximation of frictional resistance encountered by fluid moving through a reservoir. Perhaps the most important use is in connection with the proration of oil production with the decline in reservoir pressure as one of the factors involved. Such a scheme has been in effect in the Yates field of Texas for over one year, and in the proration scheme to be put into effect in the East Texas field in December, 1932, reservoir pressures are used in connection with the allocation of a portion of the allowable production from the field.

Various interesting experiments have been carried on whereby relative permeability, mentioned above, has been determined by noting the pressure drops at various rates of flow. Water level in a field may also be determined, through the use of pressure determinations at various depths to determine the point at which abrupt changes in fluid column density occur in various of the wells penetrating the oil-water contact.

The two most commonly used reservoir pressure measuring instruments are of the so-called Amerada type, described by Millikan and Sidwell,[3] and the Humble type. The first of the foregoing instruments records pressures through the deformation of a helical Bourdon tube which propels a metal stylus in a horizontal circular path, marking a metallically sensitized paper chart. The

[1] H. C. Otis: "Method of Tubing High-Pressure Wells," *Trans. A.I.M.E.*, Petr. Dev. and Tech. (1930), 293–302.

[2] J. S. Ross: "Recent Development and Use of Bottom Hole Choking," *Trans. A.I.M.E.*, Petr. Dev. and Tech. (1932), 332–341.

[3] C. V. Millikan and Carroll V. Sidwell: "Bottom Hole Pressures in Oil Wells," *Trans. A.I.M.E.*, Petr. Dev. and Tech. (1931), 194–205.

time element is supplied by a clockwork mechanism, which moves the chart in a vertical direction. The bomb is approximately 4 ft. long and $1\frac{3}{4}$ in. in diameter, so that it may be run safely in 2 in. tubing, provided that the tubing is clean and undeformed throughout its length.

The Humble type instrument acts through the extension of a coiled spring by pressure exerted against a piston. It marks a chart in the same manner as the Amerada instrument, but in a vertical direction. Horizontal motion is given the chart by means of a ratchet mechanism actuated by jerking the wire line on which the device is run. It is about the same length as the Amerada instrument, but is somewhat smaller in diameter.

Both instruments are run into wells on a regular Halliburton steel wire measuring line, which is run through a Halliburton stuffing box and a lubricator long enough to accommodate the instrument.

Care of Wells. By CYRIL THOMAS, B.Sc. (Member).

CONSIDERABLE attention has been given to the initial cleaning of walls before bringing wells on to production. It has been regular practice to wash the walls with water and/or oil after landing the oil string; or, alternatively, to scrape the walls, using oil as a circulating medium, before running the oil string.

For rejuvenation of clogged walls of stripper wells in limestone territory, chemicals have been employed to dissolve the limestone, the resulting freed detritus being subsequently bailed out from the bottom of the hole.

Chemical analysis has been extensively used to correlate waters with their geological horizons, results being plotted on a triangular or similar diagrams. Various types of salinometer or water-witch, run into the hole on a two-core cable, have been widely employed to locate water entry *in situ*. Much care has been found necessary in controlling well conditions in order that points of entry may not be masked through fresh water penetrating into the sands or through entry of the saline water becoming sufficiently rapid to cause appreciable diffusion before the survey is complete. When searching for a fresh or only slightly saline water, it has been found desirable to use a water of high salinity for control purposes.

Two factors are involved in paraffination: (*a*) the precipitation of paraffin from solution in the crude and (*b*) its subsequent deposition on conductor walls. Prevention of precipitation has been found practicable only in the case of flowing wells where, by stop-cocking or imposing back pressure to the flow string at the surface, the crude oil can be made to leave the well at temperatures above

that at which the paraffin is thrown out of solution. Failing prevention of precipitation, the alternatives are to prevent its deposition entirely or to control such deposition so that it is easily removed. In the cases of both flowing and pumping wells deposition on tubing walls has, in many instances, been avoided by the use of chemicals that coat the particles of paraffin so that they will not adhere to a surface and are produced in a state of suspension in the oil. Although not always entirely successful in preventing paraffination, such treatment has in some cases retarded deposition and rendered the deposits softer and more easily removable. Instances have occurred when similar chemicals have been successful in breaking up paraffin in a completely plugged flow string. A more general practice, however, where deposition could not be avoided, has been to remove the paraffin from time to time with various forms of scraper. One popular type of scraper is worked by the gas itself and can be used in both flowing and gas-lift wells. Preheating of the gas has been commonly adopted for preventing precipitation in gas-lift wells. Since this necessarily leads to increased temperature of the outcoming oil, obviously objectionable in the case of crude oil rich in light fractions, an alternative practice has been the periodical reversal of gas flow, production being taken alternatively from the tubing and from the space between tubing and casing. By this means it has been found possible to keep deposition in check without employing excessive gas temperatures. The Gage pump, circulating hot oil, has been found to deal satisfactorily with paraffin in the case of pumping wells.

Paraffination at or in sand faces is not likely to occur until bottom-hole pressures have become very much reduced, when the gas accompanying the oil consequently arrives at the well face expanded to a very considerable degree. Periodical closing in of the well to restore pressure and temperature conditions has in some cases been found effective in reopening the channels.

Well Surveying. By Captain D. COMINS, M.C. (Member).

UNDER the heading of Well Surveying may be included the measurement of pressures and temperatures in wells at varying depths under both static and flowing conditions; the collection of samples of crude under pressure from the producing horizon and the determination therefrom of the characteristics of reservoir crude *in situ* with special reference to its dissolved gas content, gravity, viscosity and surface tension.

Investigations of this nature have only attracted the serious attention of petroleum and production engineers during very

recent years, especially since the conception of unit operation of reservoirs has been generally accepted and aimed at where practicable.

During 1932 a special impetus has been given to the evolution of devices for measuring bottom-hole pressures, and to their wide application, by the movement in the United States, especially in East Texas, towards basing the prorated production allowances of individual wells upon a maximum allowable bottom-hole differential pressure when on production, rather than upon a percentage of their maximum potential production during short tests.

Current instruments in use, of either the indicating or recording type, are based upon various principles. These include the use of a Bourdon tube; the accurate measurement of the compression or tension of a spring; and the measurement of the compression of air. With the last type mentioned, owing to the very small change of volume at high pressures, special arrangements for magnification are necessary and any given instrument is therefore only suitable over a short predetermined range of pressures. The above-mentioned instruments are all of the type in which the readings are only available after the instrument has been withdrawn from the well and for accuracy it is essential that calibration curves should not be relied upon, but that the observed readings should be tested against a deadweight tester at surface at the same temperature as that existing in the well at the point where the reading was taken. An interesting method, by which direct observations are made at surface, is that of lowering flexible tubing of only 1/16 in. internal diameter to the desired point in the well, the well pressure being balanced by compressed hydrogen connected to the tubing, allowance being made for the weight of the column of hydrogen under the pressure and temperature conditions obtaining.

Whereas until recently temperature measurements in wells were only recorded exceptionally, in an attempt to correlate geothermal conditions and structure, these have latterly been recorded as a routine, as being essential to precision in the observation of other reservoir data. The thermometers in most general use are of the ordinary deep sea maximum indicating type, but electrical resistance thermometers are sometimes used for greater accuracy, and a recording Bourdon tube type is also in use.

In connection with the movement towards gas conservation and elimination of waste or reservoir energy, increasing attention has been paid to the collection of samples of reservoir crude under pressure in order that the dissolved gas content and physical characteristics of the crude *in situ* may be determined. It is now being more generally realised that such data obtained by laboratory

experiments, in which dead crude is regassed, may be misleading, and that reservoir samples are essential.

Little has been published regarding design of pressure sample takers. Many types are open to the objection that there is a temporary reduction of pressure, causing evolution of gas from solution, at the moment of ingress of the sample. In others, for example in the flow-through simultaneous-closing double-valve type, the possibility of contamination by crude at higher levels is not entirely eliminated. In a type recently perfected these difficulties have been avoided by means of a piston arrangement and electrical timing device.

Gas and Oil Separation. By G. McConnell.

No notable developments occurred in the general design of oil and gas separators, the designs in use during 1932 being substantially those developed and known in previous years, vertical pressure-tight tanks, equipped with various arrangements of internal baffles intended to promote separation and reduce entrainment, and having internal or external floats for control of effluent.

For dealing with high well-head pressures, the practice of employing groups of separators in series (*i.e.*, under progressively reduced pressures) was developed and extended. In some fields it was also found feasible and economical to serve numbers of wells with centralised groups of separators operating in parallel.

Detail improvements in design of liquid level control and pressure relief devices were tested with promising results, though the conventional float control and relief valve remained in general use.

Water and Oil Separation.

For the separation of non-emulsified mixtures, the usual gravity methods have been employed. Separators built to withstand high pressures have come into use: these have the important advantage of restraining the evolution of gas and thus reducing the most potent cause of emulsification. Separators, especially of the high pressure type, have commonly been equipped with automatic controls for regulation of outflow of water and oil.

Tests have been made with apparatus incorporating, in a single shell, means for separation of water, oil and gas. In view of the risk of inducing emulsification, the usefulness of such devices seems likely to be limited: if employed in conjunction with the "series" arrangement of oil/gas separators, much of the advantage of the single shell construction would be negatived.

Emulsification has been dealt with by introduction of chemicals into the casing, as well as by the use of heaters. Gas-fired heaters

of multiple-unit construction, with or without heat-exchange apparatus, have come into use, and have in some instances proved highly efficient.

Increasing attention has been devoted to the avoidance of emulsification, both by use of high pressure separators as before mentioned, and by careful design and arrangement of chokes, valves, etc. Efforts have been made to reduce turbulence of flow at such points, especially where ebullition of gas is liable to occur in contact with the oil/water mixture.

Gas Treatment. By V. V. Jacomini.

In the recovery of gasoline from natural gas, increasing attention has been given to removal of impurities from the gas. Owing to the highly corrosive effect of sulphur compounds, efforts have been directed towards their removal before the actual extraction of gasoline. Scrubbing of the gas with caustic soda solution has been successfully employed, while a patented process using triethanolamine or diethanolamine as absorbent has also been used. This latter process lends itself to a modification in which recovery of pure sulphur is effected, the absorbent in this case being a solution of triethanolamine thiosulphate: the absorbent, after saturation with hydrogen sulphide, is regenerated by contacting with gaseous sulphur dioxide, pure sulphur being formed and removed by flotation. One-third of the recovered sulphur is burned to produce the sulphur dioxide necessary for regeneration.

The most common method of extraction of gasoline has been by absorption in oil, the absorbers being usually operated at from 30 to 60 lb. per sq. in. gauge pressure, although much higher pressures have been employed. Recovery of gasoline from the oil has been effected almost universally in stills of the fractionating type, using gasoline as reflux; the single stage still, running at about 30 lb. gauge pressure, shows signs of giving place to the two-stage system in which the first still operates at about 80 lb. gauge pressure and the second at much lower pressure.

Recovery plants recently built have in most cases incorporated stabilisation apparatus, whereby the vapour-pressure of the finished gasoline may be reduced to any desired figure. A further development during the past year has been the cracking of the waste vapours/gases from the stabilizer to produce high anti-knock spirit: this has not yet passed the experimental stage.

Oil Mining. By A. Pellissier.

The methods of working at Pechelbronn, in connection with the recovery of petroleum by means of underground drainage, have not developed to any great extent since 1930.

The principal modifications introduced since that date are, however, given below.

The most important have been in connection with the investigation of strata or areas, which lend themselves to development by underground galleries.

As is known, the exploitation of underground drainage by wells and galleries is considered to be complementary to the normal method of drilling; the aim being to recover, as far as possible, the crude oil left in the sand after normal production by pumping. From this point of view, it can be placed in the same category as the "repressuring" processes and the "Marietta process." It can, however, be distinguished from these in that it can pass from being a secondary method to a principal method of extraction, the drilling which preceded it being then considered more in the nature of exploration work productive of crude oil rather than as actual development work.

This has been the main direction in which development has proceeded since the wells and galleries were first put down at Pechelbronn. It has of course been confined to those areas of the basis in which underground drainage promised to be feasible and profitable.

In fact, in a recently discovered area which showed normal conditions of depth, of multiplicity of layers, of slight dips, absence of water-levels under strong pressure requisite for underground drainage, preliminary development by drilling was undertaken, but this was confined to such wells as were necessary to fix the extent of the bed (marginal waters, faults), its continuity, its internal structure and also the oil and water bearing levels. Instead of placing the borings at a distance of say 100 metres, which was the practice until recently, the distance here is 300 metres. Drilling and pumping costs are thus reduced, as galleries may later be used to draw off all the remaining crude oil.

Similarly, important progress has been made in the study of the strata by coring and the study of the occurrence of liquids (sweet water, salt water, crude oil, gas). Drilling methods have been modified to some extent as a result of these investigations.

As is well known, the drilling apparatus at Pechelbronn comprises both high-speed water flush percussion drills with water jet and cable tools. While the latter method is specially adapted to sampling of strata and indication of oil and water, the work described is done mainly by the former method, and a large number of rigs are still in use. A method has been developed of adding chemicals to the flush water to form a kind of freezing mixture. This reduces caving and keeps the drilling in a more solid state. It is found that samples thus obtained, being semi-frozen, retain

and bring to the surface traces of any liquid that may be contained in the strata. They are moreover usually sufficiently large to reveal the fossil or other structure clearly, on simple washing with fresh water. Samples of oil-sands have been obtained by this method much more readily than by conventional coring methods. Among other methods of exploration especially important for subsequent development by means of galleries, mention may be made of the following:

Direct sampling of water from strata, with study of salinity;
Electrical determination of salinity, etc., at various depths:
"Electric coring" on the Schlumberger system.

TRANSPORTATION AND STORAGE.

Pipe Lines. By A. C. HARTLEY, A.G.G.I., M.Inst.C.E. M.I.Mech.E. (Member).

THE tendency in pipe-line construction for engineers to specify thinner wall higher-tensile pipe noted in last year's report on "Progress of Napthology" has continued during 1932, and lap-welded and seamless pipe to the old specifications have been less used.

There has been rapid and continuous progress in the manufacture of improved seamless pipe and in various types of electrically-welded pipe, with a large variety of wall thicknesses in the following grades of steel specified in A.P.I. Pipe Specification L.5:—

	Bessemer welded.	Open hearth welded. Class 1.	Class 2.	Class 3.	Seamless. Grade A.	Grade B.	Grade C.
Min. tensile strength lb. sq. in. ..	50,000	45,000	48,000	60,000	48,000	65,000	75,000
Yield point lb. sq. in.	30,000	25,000	28,000	35,000	30,000	38,000	45,000
Elongation 8 in. per cent.	18	22	20	18	—	—	—
Elongation 2 in. per cent.	—	—	—	25	40	25	20

A minimum ultimate tensile strength of 60,000 or 65,000 lb./sq. in. with an elastic limit at about one-half the ultimate and 0·20 to 0·30 carbon with manganese sulphur and phosphorous content of varying amounts according to the process of manufacture have been usually specified. In many cases a higher carbon content giving an ultimate strength of from 70,000 to 90,000 lb./sq. in and an elastic limit of not less than 40,000 lb./sq. in. has been used. There has been a tendency to design the wall thickness to be just sufficiently strong to resist the internal fluid pressure and such other stresses as the pipe may be exposed to, and to provide protection against corrosion by the use of special coatings rather than by the

use of the extra thickness of steel which has been common practice in the past.

The reduction in new pipe-line construction work during the past year has enabled manufacturers to carry out intensive research work, and pipe-line engineers have been able to study the economic aspects of pipe-line projects with greater care. Much attention has been paid to the selection of the tensile strength of steel and thickness of wall of pipe that would best suit the conditions in any particular case. The use of very high-tensile steels is still in the development stage in both manufacture and in methods to be employed in welding in the field. With high tensile-steel pipe it is also more difficult to make the normal bends required in the field, and heating of the pipe is necessary with consequent risk of damage. Factory made bends of the required angles have been used in several cases to avoid the necessity for bending in the field. In certain important projects, even though the saving in transport costs due to the reduction in tonnage would have been unusually great, seamless pipe of Grade "B" has been selected in view of the greater certainty with which the welding processes, equipment and personnel could be selected and uniformly satisfactory results ensured.

Development work, with high tensile pipe, however, continues, and extremely high-tensile steel with an ultimate strength of even 100,000 to 125,000 lb./sq. in. with an elastic limit of 70,000 lb./sq. in. and a thickness of only $\frac{1}{8}$ in. has been experimented with, together with a vitreous enamel protection which it is claimed adheres to the pipe with great tenacity.

The usual 12-in. pipe with a wall thickness of $\frac{3}{8}$-in. weighs about 131 tons per mile and is suitable for about 700 lb./sq. in. working pressure. The recently developed grade of pipe weighs less than 60 tons per mile for the same working pressure. The higher tensile steel is more expensive in cost per ton, but it has been found that the thinner pipe gives such a saving in weight of steel, in cost of freight and in transportation cost that its use becomes economic in certain cases.

Experience has, however, been obtained with higher and higher tensile steels, and the difficult conditions of the past year have led to definite progress towards the use of more economical pipe.

There has been steady progress during the past year in methods of construction, and the period of reduced activity in the laying of new lines has been used by manufacturers to improve ditchers, tractor cranes, welding equipment, pipe-wrapping machines, etc., with a view to improving workmanship, and at the same time increasing the speed of construction and reducing costs.

Welding processes have been further developed and welds of more uniform quality, using much smaller quantities of electrodes, have been made at speeds far greater than before.

The year has produced improvements in both the electric arc and oxy-acetylene welding. In electric welding the small electrodes and welding currents of 150 to 200 amperes formerly used have been almost entirely replaced by the use of large diameter electrodes working with amperages of 300 and 400 and in some cases up to as high as 600. The electrodes used with these high ampereages are coated with a flux to protect the molten metal in the weld from the atmosphere, and there has been great improvement in the prevention of formation of oxides and nitrides, which cause porous and brittle welds. Flux-coated electrodes have been developed to produce welds under rapid working conditions in the field, which will develop the full strength and elasticity of Grade "B" pipe, and progress has been made with special electrodes for the very high tensile pipe referred to above.

Research has been carried out to study the phenomenon within the arc, and metallurgists and chemists have assisted the engineer in improving each phase of the welding process, with the result that increased speeds of operation in the field have been realised.

The new method of oxy-acetylene welding introduced to compete with the increased speed of electrical welding has been further developed and extensively used. A carbonising flame is used in place of the neutral flame employed in the original ripple welding method, and the excess carbon reduces the oxides present in the parent metal and prevents oxidation of the molten metal, while at the same time diffusing into the iron and forming an alloy with a melting point several hundred °F. below that of steel.

When steel with a melting point of about 2730° F. is heated up to about 2200° F. by means of a carbonising flame carbon is absorbed and a layer of steel melts at the lower temperature, thus forming a carbonaceous flux. The carbonised surfaces melt uniformly and more quickly than the steel immediately beneath them, thus making it possible to fuse the weld metal and the walls of the vee with only slight melting of the base metal.

Welding rods usually about 1·16 in. larger in diameter than those used for the old ripple-welding process have been used, and by holding the flame close down in the centre of the vee both walls are prepared for fusion at the same time. The heat generated, owing to the small amount of melting of base metal, is much reduced and the angle of the vee and the clearance between the ends of the pipes have been reduced owing to the smaller provision which has had to be made for expansion. The result is the use of a smaller amount of welding rod, a considerable saving in the amount of gas

used, and greatly increased speed of work while maintaining the high quality of the weld.

The use of the new method of oxy-acetylene welding with the ordinary blow pipe has halved the time which was formerly required for the making of a given size of weld.

A new type of blow pipe has been developed which further reduces the time of the welds and gives a speed which has been claimed to be four times as fast as the old ripple type of welding with a corresponding reduction in gas consumption.

The welding rod, guided in the proper position with respect to the welding flame by the holder, is allowed to feed vertically by its own weight into the puddle. It is preheated to a bright red heat by a small flame about 1 in. from the end, and after being thus heated is melted rapidly into the puddle by the welding flame lower down. The vee surfaces are brought to a melting condition by the welding flame at the same time and the puddle progresses ahead as the rod is melted into it. The welding is done by the back-hand method in that the completed weld is on the opposite side of the rod from the welding flame. The same type of flame is used as with the hand blow-pipe. The blow-pipe handle is connected by a stem to the head holding the two tips and rod holder, while the entire device is supported over the joint by a carriage having runners which are adjustable for each diameter of pipe. The runners support the device only at the sides and permit the operator to raise or lower the blow-pipe handle. Raising the handle makes the flame bear more upon the rod, increasing the deposition of the metal, while lowering the handle has the opposite effect and at the same time causes the welding flame to heat the vee more rapidly.

As an example of the increase in speed claimed to be possible with the new blow-pipe on a line of 125 miles of 20 in. natural gas line with a wall thickness of 9/32 in., the average time for making rotation welds was stated to have been decreased from 24 minutes to 17 minutes; the average number of welds made in a 9-hour day with the semi-automatic blow-pipe being 23 to 25. The new process has been used on 360 miles of oil-line in a series of loops from a point in Oklahoma to Chicago. This line consists of 190 miles of 12 in., 90 of 10 in. and the balance of 8 in. The pipe was furnished in random 40 ft. lengths of wall thicknesses of approximately 11/32 in. of 12 in. and 10 in. sizes, the 8 in. size being slightly less. The pipe ends were bevelled so as to have an included angle of 75°. In spite of unfavourable weather conditions and greatly varying conditions of right-of-way, the welds made per 9-hour day averaged about 25 to 30 on the 12 in., 30 to 35 on the 10 in., and 35 to 40 on the 8 in., the time for welding rotation joints being 13 to 16 minutes,

11 to 14 minutes and 8 to 10 minutes respectively for the 12 in., 10 in. and 8 in.

Special welding rods containing silicon and manganese to prevent the formation of blow-holes and of very low carbon content so that the amount of carbon in the finished weld can, with the amount of carbon introduced by the flame, be the same as that in the parent metal, have been developed and enable sound welds of high ductility to be produced at high speeds. Joints have been made in the laboratory on plates of more than 90,000 lb./sq. in. tensile stress, and the test pieces have broken away from the weld.

During the past year a considerable number of lines have been laid using reclaimed scrap pipe. The collars were cut from the old lines by means of pipe-cutting machines which bevel the pipe ends as the cutting is done. When using a pipe roughly cut in this way it has been found desirable to lower the amount of excess acetylene and to approach more nearly to a neutral flame, because of the additional surface metal of the pipe which has to be melted into the puddle to enable all irregularities to be removed.

During the past year the double-bell type of joint with internal sleeve or back-up ring has been extensively used. The ends of the pipe have been swelled to form the bell and the sleeves have been cut from pipe of the same specification. The clearance between the sleeve and the bell has been arranged to be as small as possible without causing difficulty in the field in inserting the sleeves.

As noted above, there has been a tendency to bevel the ends of the pipes so as to form a smaller included angle for the welding metal, and the 90° included angle previously used has been reduced in many cases to 60 or even 50°. The use of the smaller, included angle and the back-up ring, has enabled the speed of welding to be greatly increased.

During the year a back-up ring of paper has been introduced, and has given promising results. The paper ring is designed to withstand the heat of the first run of welding, but to be burnt up completely without leaving any ash by the greater heat of the second run.

Portable testing machines have been developed which enable test pieces cut from the welds in the field to be tested immediately in the presence of the welders doing the work. These pieces should always break outside the weld if full advantage has been taken of the latest welding technique, and the work properly done. Such tests, made at random, have proved very useful in keeping the welders up to their work.

Research work and experimental work have been vigorously carried out during the year on the causes of corrosion and the best means of protecting the pipe, and further data is now available

with regard to the effects of electric currents on the pipe in the earth.

Efforts have been made to develop coatings and wrappings which will resist the soil stress when the pipe is in the ditch. The practice of wrapping pipe at the mill has been extended, and there has been considerable development in machines for wrapping pipe in the field.

Maintenance.—Manufacturers of equipment have produced improved tractor cranes and accessory equipment for uncovering, handling and back-filling pipe-lines.

Ploughs have been developed having heavy steel prongs to extend down on either side of the line, and loosen up the earth sufficiently to permit of raising the line. A special drag-line bucket has been developed which will drag the dirt to one side, leaving a wide ditch in which the reconditioning work can be done when the condition of the line makes it inadvisable to attempt to raise it out of the ditch.

A new type of travelling pipe-cleaning machine has been developed with a double cleaning head, thus rendering unnecessary the previous practice of running either two machines near each other or one machine twice over the pipe. Considerable economies have been claimed to result from using the double-headed machine.

Electric welding continues to be used for welding up pitted spots when they are not too deep. For dealing with pits which are leaking a steel plate fitted with a piece of rubber has been placed directly over the hole. The plate has been shaped to conform to the contour of the pipe and a special hydraulic jack device has been used to press the plate tightly against the pipe. The plate has then been welded into position while the rubber has stopped the leak. This method has proved less expensive and more satisfactory than the old practice of using heavy cast iron clamps with "U" bolts to hold them in place. It has been found increasingly necessary during the year to remove the old type of clamp and weld on plates to form permanent repairs.

A new type of pipe-wrapping machine has been developed for use in the ditch and requires only 8 in. of clearance around the pipe. Considerable mileage of old screwed and coupled pipe has been reconditioned by cutting out the collars and relaying with welded joints.

An oxy-acetylene pipe cutting and bevelling machine has been developed which does this cutting very economically, and at the same time bevels the end of the pipe to any desired angle. Cutting and welding by this means has been so economical that it has proved worth while to utilise any good lengths of a corroded pipe which exceed about 30 in.

Maintenance work has become more important as time passes and the lines have been longer in the ground. Leaks are expensive even though through very small holes, and there is always a risk of fire. Pipe-Line companies have, therefore, paid very considerable attention to reconditioning and have not been slow to utilise the improved equipment offered by the manufacturers.

Much research work has been undertaken with a view to determining the factors in the nature of soil which cause corrosion, and which determine its intensity. Methods have been developed, and in some cases successfully used to forecast corrosion conditions; one method is an electrical one in which a potential is applied across two electrodes in contact with the soil, and the current flowing is measured by a sensitive milliameter. In general, it has been found that high moisture and soluble salt content, both of which cause corrosion, lower the electrical resistance and so give a useful indication.

It has been more and more realised that movements of the pipe owing to changes of temperature have been the chief cause of the failure of protective coatings. Efforts have therefore been made to increase the resistance against soil penetration of primers, hot applied enamels and pipe-wrappings, and much improved materials are now available.

Coir Fibre produced by a new process has proved to be almost completely rot proof and capable of being impregnated with bitumen. It is extremely strong, and experiments already made indicate its use may prove to be a great advance in the manufacture of pipe-wrappings.

During the year thin gauge copper has been made available and has been proposed for use in pipe wrapping. This copper sheet has a minimum thickness of ·0017 in. and has been produced in continuous lengths up to 48 in. wide. It is claimed that the copper, besides preventing moisture and stray currents from reaching the pipe, is owing to being both tough and smooth, able to resist soil stresses to an unusual degree, because the soil does not stick to the foil, but moves easily past it. This is a new method which will be watched with interest, but as yet there is no experience on a large scale.

One of the outstanding developments during the past year in pumping station design and one having as its object the reduction in the capital costs usually involved in tanks, large buildings, heavy foundations, etc., is the new type direct-connected unit known as the "Rannett" pump. This pumping unit has been designed for erection in the open and without any covering whatsoever. It consists of a 700-h.p. 3-phase 2300-volt induction motor direct-connected to an 8-stage centrifugal pump and running at

3600 r.p.m. The motor and pump are connected together through a central spacer section so as to prevent deflection from any external forces. The stator laminations of the motor are inserted in a double wall-housing, and the inner housing is made from a forged-steel billet. The outer housing is made of heavy welded sheets and the end plates and bearings are carried in such a manner that the rotor and bearings can be removed without interfering with the space between the double shell. The oil being pumped enters the double wall section of the motor through which it flows spirally and laterally, thus cooling the motor. The 8-stage pump is arranged with two sets of impellers of four stages each, arranged in opposition to equalise the end thrust, and to take the high-pressure discharge from the centre of the pump between the sets of impellers. The inlet and outlet flanges for the oil are arranged in line with the motor and pump shafts to facilitate connecting up on installation.

A self-contained lubricating system for the complete unit is provided consisting of an oil pump direct-driven at the end of the pump shaft, and a heat exchanger for cooling the lubricating oil by means of the oil being pumped situated in the spacer section between the pump and the motor. Very high efficiencies have been claimed for the motor due to the elimination of windage losses. The motor is of explosion-proof design and can operate safely in an explosive gas. Provision is made for the gland leakage from the pump to be led by gravity to a 1000-gallon tank fitted with Mercoid switches controlling a small motor-driven pump, which returns the leakage periodically to the main pump suction. A great advantage of this design is that it enables the complete pump to be tested in the manufacturers' works, and that it can be shipped to the site as a complete unit weighing only 18,000 lb. for a 37,000 barrels per day capacity. Sling lugs are provided for easy handling, and it can be shipped without crating. The motor has been designed for direct starting across the line voltage, and the motor-driven oil-gate valves, etc., have been designed for automatic operation of the station.

Further development has taken place in the more conventional types of electric motor-driven centrifugal and reciprocating pumps, and in Diesel engine-driven pumps of both types. The remarkable extension of electrical transmission systems during the year has encouraged the use of electric motors for driving pumps, but the costs for this power are still high in many cases compared with the costs of power provided by Diesel engines. The capital cost is, however, lower than for Diesels, the foundations are cheaper, smaller buildings are required, and a station can be more quickly erected and commissioned. A greater proportion of the investment

can be recovered if the plant has to be moved, and these advantages have often been found to outweigh the disadvantage of higher running costs. Electric motor-drive lends itself readily to automatic operation and stations have been worked from a distance by the sending of the necessary control signals over a single pair of wires. Visual type signal-boards have been provided to keep the distant operator fully informed with regard to line pressures, bearing temperatures, etc., and automatic equipment shuts down the station if anything abnormal occurs. Stations have also been designed to operate solely by means of variations in the oil pressure and without the complications of electrical signal and control apparatus. There has, however, not been any very marked extension in the use of fully automatic stations, and it is doubtful whether the saving in operating costs justify the extra cost and complications they involve.

When it has been anticipated that a pipe-line system would have to run for prolonged periods at reduced throughput care has been given to the choice of suitable electric motors, and in a 2-motor station one motor has been of a ·8 leading power factor synchronous type, and the other of a two-speed squirrel cage type. It is claimed that this combination has enabled the station to operate a full load, three-quarter load and half-load capacity with a minimum of power consumption and a power factor of over 90 per cent. at all rates of pumping.

Reliable diesel engines running at higher speeds have been developed during the past year, and when driving centrifugal pumps through speed-up gears have provided a pumping unit combining low capital costs with low operating costs to a remarkable degree. When minimum operating costs are required over a long period of time the extra cost of reciprocating pumps with their more expensive foundation and building, but greater overall efficiency, have been justified. Pump efficiencies of 90 per cent. or slightly more have been regularly obtained and maintained after a station has been running for some time. Both duplex and triplex pumps have been used according to the required capacity, but there has been a tendency to use triplex pumps for lower capacities than formerly owing to their more even torque on the diesel engine and more regular discharge of oil. A compensator cylinder directly connected to the discharge manifold and having a plunger operated by cams on the main shaft has been developed to average out the rate of discharge from reciprocating pumps. During the period in the cycle when the pump is delivering more than the average quantity the cams allow the piston in the compensator to be withdrawn, thus absorbing the surplus. When the pump is discharging less than the average quantity the cams push forward

the plunger and make up the deficiency; it is thus possible to have a constant discharge from a reciprocating pump.

Fluid ends of pumps have been made both forged and cast, with a tendency towards an increase in the latter construction, with the development of special grades of cast iron and semi-steels. The valve boxes have been cast with the pump barrels and the oil passages have thus been shorter and more direct, so reducing the volumetric clearances and improving the suction conditions. Much attention has in fact been paid during the past year to the improvement of the flow conditions of the oil through the suction manifolds, the suction valves, the barrel and exhaust valves in order to obtain good efficiency when pumping "live" crude which will gas freely when its pressure is reduced and when it is subject to turbulent conditions.

Stations have been built both with and without fire walls between the engines and the pumps. When no fire wall has been provided all electrical generators, switchboards, motors, lighting fittings, etc., have been made flame-proof or explosion-proof, and the tendency appears to have been to use a fire wall of comparatively cheap construction and reduce the cost by using standard industrial electrical equipment in the engine room. Provision of electrical power has usually been made by driving generators or dynamos with multiple vee belts from the main engine-drive shaft. Alternating current has been chiefly used, but direct current has been used in some cases because of the greater ease with which machines can be paralleled, particularly when the operating conditions of the pipe-line demand flexibility in throughput and therefore necessitate the running of the main pumps and engines at reduced speeds. With direct current there is no difficulty at reduced speed, such as the change of frequency with consequent change of speed in all motors being driven, which is the case with alternating current. Generation of electrical power by belt-driven machines from the main engines has proved so reliable that recent stations have been designed with the whole of their auxiliary equipment, such as centrifugal water pumps, air compressors, lubricating oil centrifuges, electrically driven. The reliability of the diesel engine has been greatly increased, and its operation costs greatly reduced by the attention paid during the past year to the fitting of suitable air filters on the air-inlet pipe to avoid the introduction of dust to the cylinders, and by adapting improved lubricating oil and cooling water systems. Air filters of the wet oil readily cleanable type have been developed in great variety, and probably the most successful have been those which provide for a preliminary dry separation of as much dust as possible followed by a wet oil type of element to take out the dust more difficult to

settle. This arrangement has enabled more efficient service to be given over a longer period without attention.

Lubricating oil systems have been arranged to provide for either the continuous cleaning of a portion of the lubricating oil, or for the withdrawal of the whole of the oil as a batch and its replacement with reconditioned or new oil during the running of the engine. In the latter case provision has been made for passing a quantity of new oil through the engine oil tank greatly in excess of the amount normally in circuit to ensure the removal of the whole of the dirty oil. Centrifuges have been extensively used in both systems of cleaning, and more recently filters of stream-line or other types have been successfully developed for this service. Experience has shown that money spent on keeping the oil in as clean a condition as possible has been repaid many times in reduced engine maintenance and repair expenses, and that such treatment is specially necessary with engines running on certain pipe-line crudes, which are very different from the good quality diesel fuels generally supplied to engines.

Engine-cooling water systems working through heat exchangers with the pipe-line oil on a closed circuit have been almost universally adopted. They have been designed with very little exposed water surface so as to reduce evaporation losses and aeration to a minimum. These systems have been so successful that stations have been located entirely with regard to pipe-line conditions and without regard to the conditions of water supply in the neighbourhood. Closed water systems have needed make-up of only a very few gallons per week, and scale formation in the engine water-jackets has therefore been almost entirely eliminated. Regular shut downs for cleaning and emergency shut downs for cracked cylinder-heads or liners have almost become things of the past. Heat exchangers were previously installed on the suction pipes to the pumps, but necessarily added resistance to the suction system to the detriment of the smooth running and volumetric efficiency of the pump, even though the pressure drop was limited to 1 or 2 lb./sq. in. at the expense of great increase in the size of the heat exchangers. This disadvantage has been overcome in certain installations by the introduction of a low head electrically-driven centrifugal pump for boosting the oil through the exchangers and feeding the main pumps. Another piece of running equipment was, however, thus required, and the more recent tendency has been to design the heat exchangers to withstand full delivery pressure and install them on the delivery line of the main pumps. Much smaller heat exchangers have been used under these conditions, and they have been so arranged as not to receive excessive shocks and vibrations.

Victaulic joints have been used to facilitate the removal of the exchangers for cleaning, etc., to provide for expansion and to assist in reducing shocks. It must, however, be remembered that any leakage in the exchanger, even though the chance is remote, will result in oil contaminating the engine cooling water, whereas if the heat exchangers are placed on the suction lines leakage will be less likely due to the lower pressure and will take place from the water side into the oil.

Steel tubes and tube plates have been used with success in most installations, and if corrosion has become apparent it has been stopped by raising the pH number of the water to about 8 with soda ash and the addition of sodium chromate, to make an 0·05 per cent. solution and bring it to a passive condition. Heat exchangers have generally been designed with the oil in the tubes and the water in the shell, and this has proved very desirable if there is any fear of sludge or wax being deposited from the oil. When, however, the oil has been sufficiently clean it has been found that a much smaller heat exchanger could be designed for a given duty with the oil in the shell.

The large increase in the use of diesel engines for all purposes has resulted in much more knowledge of critical speed conditions, and diesel drives for pumps have been designed to avoid any serious critical speeds within the range of the running speeds. Drives with two flexible couplings with a drive shaft between have been more frequently used, and have proved of great advantage when any trouble has been experienced with foundations. They have run satisfactorily with an appreciable degree of misalignment. Flexible couplings, usually running in an oil bath, have been used of either the type providing only for misalignment and end float, or with an additional provision for torsional flexibility if the drive system has needed a damping effect to reduce critical speeds of orders which cannot be avoided under certain circumstances.

Reciprocating pumping stations have been operated with suction pressures as a continuous system, without floating tankage, in order to reduce evaporation losses. Very accurate adjustment in the pumping rate at the various stations is necessary, and flexibility has been provided by means of a 1½ in. by-pass connection and meter between the discharge and suction sides of the pumps. This provision has been particularly necessary with electric motor-driven pumps, of which the speed cannot be accurately varied, but even then it is claimed that only 2 per cent. of the oil pumped had to be by-passed. It has been claimed that lower operating costs have obtained and better operation of the pumps than in the usual system of having floating tankage.

Tank Steamers. By DOUGLAS H. JACKSON, M.I.Mar.Eng., M.I.N.A. (Member).

WORLD marketing conditions during 1932 precluded notable developments in ocean transport of petroleum. With tonnage surplus to transport requirements in all directions, attention was mainly directed towards economies in operation of existing units. Development of rationalised types of construction such as the twin-longitudinal bulkhead system proceeded slowly, several vessels of this class being put into service. Otherwise hull design as a whole remained more or less standardised, being to a large extent dictated by the limitations and requirements of the International Freeboard Convention's findings. The more radical developments such as "Maierform," "bulbous form," etc., were not applied to tanker construction. Service speeds showed the expected tendency towards moderate general advance, though one outstanding example showed designed sea speed of 16 knots and was reported as exhibiting unusually high propulsive efficiency.

More intensive study of the relative incidence of standing charges and fuel costs having indicated the true economic speed of many individual tankers as approaching their full designed speed, attention has in many cases been led to the problem of balancing advantages of the policies of running whole fleets at uneconomically low speeds, and operating some units at high (*i.e.*, economic) speed while paying laying-up charges on other units.

Diesel engines were predominant in the propelling machinery of new vessels, although there were signs of a definite tendency to retain steam propulsion—ordinary reciprocating engines, Bauer-Wach and geared turbine—for vessels trading on short voyages and making rapid turn-rounds. Cargo pumps were in most cases steam-driven, but special trade requirements led in some instances to novel arrangements of cargo piping in conjunction with increased numbers of pumping-units. Developments in this direction were hampered by conflicting codes of port regulations which still showed a deplorable lack of uniformity, especially with regard to the now widely permitted practice of continuous discharge of petroleum spirit with tankers' own power. Although local conditions must necessarily be respected, it is to be hoped that some sort of international model code may be promulgated. A suitable central authority or convention for the drafting of such a code is at present still to seek.

Barges.—Suffering under the same restrictions of trade stagnation, developments have been slow and have followed normal courses. The design of barges being largely controlled by various port authorities, uniformity of practice has been unattainable, especially

as regards vessels for carriage of petroleum spirit. Double-shell construction was still enjoyed by many authorities notwithstanding its known dangers. Machinery for self-propelled barges became practically standardised as of Diesel type, thanks to notable developments and improvements in such engines of relatively small power and light weight. The bearing of local regulations on relative safety of self-propelled *versus* towed barges remained undefined, with a tendency towards increased toleration of the former. In this connection the psychological aspect *vis-à-vis* the barge crews seems worth consideration.

Increased attention was paid to arrangements for cargo-pumping and gas-venting, equipment in this respect approaching the standard set by ocean tankers. Welded construction received further attention, and seems likely to be increasingly adopted in the future.

Pollution.—As usual, two aspects of the problem called for attention. (*a*) Pollution of harbour and territorial waters; (*b*) pollution of different products carried by the same vessel. As regards (*a*), the year saw rather fewer new inventions lodged, most successful separating devices depending essentially on the principle of settling. In many cases the need for discharge of heavy oils into harbour waters was avoided altogether, while the use of separators of tried types erected on shore or carried in *ad hoc* barges continued as a standard safe practice. The second aspect of pollution was met by adaptations of pumping plant and lines permitting either positive separation of product from product or thorough clearing of lines with water or degradable oil.

Natural Gas Transport. By A. C. HARTLEY, A.C.G.I., M.Inst.C.E., M.I.Mech.E. (Member).

THE tendency noted in the case of oil-pipe lines for the use of high-tensile steel pipe to increase has been even more marked in the case of natural gas lines. Pipes of larger diameter are used, and the savings to be made are greater. The disadvantage of not being able to make field bends without heat on high-tensile pipe does not apply to the same extent, as the larger diameter used tends to prevent their being made even with low-tensile pipe.

Fire bends in the field have been fairly satisfactory with thick-walled low-tensile pipe, but have proved a difficult problem with higher-tensile, thinner-walled pipe. In the case of one line, large numbers of 20 ft. lengths of pipe with three 7° bends formed at intervals along their length by means of corrugations have been used. These provided bends of 21°, and by cutting between the bends angles of 7° and 14° became available. Special couplings have been produced with $2\frac{1}{2}$° and 5° angles to take care of smaller

bends. With this combination of bends and couplings it has been possible, almost completely, to avoid field bends.

Electric-welded and seamless pipe have superseded other types of pipe, and the adoption of the newer methods of fusion and resistance welding have enabled pipe of longer lengths to be made at rates of output per mill that would formerly have been thought impossible. The new pipe has no mill-scale either inside or outside, and wear and tear of regulator and gate valves due to abrasion has been greatly reduced, while at the same time a much better surface has been provided for the application of protective coatings.

Methods of jointing pipe in the field have been improved, and both the electric welding and oxy-acetylene welding methods described in detail in the case of oil-pipe lines have been extensively used.

Couplings with special gas-resisting rubber gaskets have also been extensively used, particularly to provide for expansion, in which case they have been used at regular intervals between sections with welded joints.

Full advantage has been taken of the improved ditchers, tractors, air compressors, back fillers, unloaders, etc., for speeding up construction where the country has been sufficiently smooth to allow of their economical use.

Experience has tended to show that the cost of protecting large gas lines from corrosion by heavy coatings and wrappings is only justified at isolated places in a line where corrosion is likely to be severe.

Much attention has therefore been paid to the examination of soils to determine the amount of corrosion to be expected, and definite improvements in primers, hot applied enamels and in pipe wrappings have been made.

There has been a tendency for bridges to be used for the carrying of pipe across rivers instead of the older method of multiple small-diameter pipes connected at considerable distances apart into headers on either side of the river. Bridges have usually been designed to permit of duplication of the line at a later date.

Higher gas pressures have been used with the introduction of higher-tensile steel pipe, and have made necessary the use of more powerful compressors. These have generally been gas-engine-driven, and of as much as 1000 to 1500 h.p. Twin-tandum horizontal double-acting 4-cycle units have tended to displace all other types for any but the very small sizes; making them double-acting results in saving in weight, cost per horse-power and floor space. Horizontal is preferred to vertical design on account of accessibility.

Very rapid expansion has been noted during the past year in the liquefied gas industry, and there is every indication of further growth at an increasing rate, having regard to the extent of the available supply and the small part of the possible markets so far supplied.

It has been found that the chief use of "bottled gas" is in the moving zones between areas where population is too thin to pay for its distribution, and where population is so dense as to justify regular pipe systems of gas distribution.

The gas supplied has been pure propane, mixed propane and butane, pure butane and pure pentane. Pure propane is self-vaporising, mixed propane and butane has been used with a separate vaporiser, whereas pure butane has been vaporised at the burner.

Liquefied gas plants have been erected for the purpose of enriching manufactured gas, and have also been extensively used to supplement ordinary gas plants when dealing with unusually heavy peak loads of short duration.

Butane has been increasingly used by automobile and other metal working plants, fruit warehouses and other industrial uses where a flexible supply of high-heat-value fuel capable of very close regulation has been required.

More than 100 central liquefied gas plants have been erected in the United States, and the majority are butane-air plants supplying gas of 540 to 570 B.Th.U.s per cubic foot, and the remainder for the most part distribute a gas of much higher B.Th.U. value, some of them supplying pure propane of 2500 B.Th.Us. per cubic foot.

Tank wagons capable of withstanding the necessary pressure have been developed for the distribution of liquefied gas, both by road and rail, and bulk shipments have been made in specially designed tankers. Improved apparatus has also been developed for use at the consumer's premises.

Storage. By A. C. HARTLEY, A.C.G.I., M.Inst.C.E., M.I.Mech.E. (Member).

THE chief item of interest in connection with steel tankage during the past year has been the greater use made of welded construction owing to the developments in the art of welding already referred to above. It has been realised that welds can now be relied upon to develop the full strength of the plate, and that, short of actual failure, a welded joint will always remain oil-tight if properly made. Thinner plates have been used than would be possible with riveted construction, and all factory work on the plates has been eliminated, with consequent large savings in the erected cost. Many tanks of

80,000-and-90,000-barrel capacity have been made of entirely welded construction.

Tanks of spheroid shape have been built in order to provide, in conjunction with welded construction, more economical storage than is possible with the standard cylindrical tanks. Their construction has required less material than cylindrical tanks of equal capacity, because the stresses in a spheroid due to double curvature of the plates are less than in a cylinder. Two 80,000-barrel Horton spheroids, 136 ft. in diameter by 40 ft. high, have been erected in Texas. They have flat bottoms of $\frac{1}{4}$-in. plate resting upon a graded earth-base and supporting interior columns which carry the roof. Truss frames were used to reinforce the sides, the shell was of $\frac{3}{16}$-in. plate, while the roof includes $\frac{3}{16}$-in. and $\frac{1}{4}$-in. steel plate. All the joints were lap-welded by the electric shielded arc process, and the tanks were completely welded in the field without any preliminary shop fabrication.

Oil Measurement.

VARIOUS technical advances were made in methods of measurement, during 1932, but on the whole, the subject remained in an unsatisfactory state, there being no universally accepted standards. There was, however, a definite move towards acceptance of measurement by volume corrected to standard temperature so far as crude oil, kerosene and gasoline are concerned. For fuel oils and other heavy products, weight remained the customary basis of measurement.

In measuring technique, tank-dipping methods have received attention in the direction of standardised dip-rods and tapes, calibrated at defined temperatures. Types of dip-rod and dip-hatch have been developed to minimise fire risks. Calibration of storage and measuring tanks has been treated on a more scientific basis, and tentative standard methods have been advanced.

Meters of high accuracy have been available for a considerable time. During the period under review many of these appliances were improved in detail and made more sturdy and more reliable. In consequence they met with wider acceptance, and there seems a prospect that in some direction approved types of meter may supersede tank-dipping altogether.

Temperature correction, in the case of tank-dip measurements, remained subject to appreciable errors, the technique of temperature observation in large bodies of liquid being inherently dependent upon the personal factor. As applied to metered measurements, such corrections offered less difficulty. Certain types of meters have been used which incorporate devices for automatic temperature correction.

Reliance on published tables of expansion-coefficients has, in some important instances, proved to be misplaced. This difficulty has led, for special purposes, to corrections being applied on the basis of specific gravity, notwithstanding the known objections to the use of hydrometers and the like.

Fire Prevention and Fire Fighting.

THE petroleum industry is now realising fully the vast loss it suffers annually through fire, and the importance of fire prevention and organised fire fighting. As a result, greater attention is being paid to maintaining tankage in a gas-tight condition and keeping lease premises clean and orderly.

The practice of bringing in wells through the flow line (instead of the older method of swabbing and allowing the oil to escape) has been almost universally adopted, and has resulted in a marked decrease in the number of fires from this source. In the East Texas field, where the method was used uniformly since the opening of the field, not a single fire has been experienced in bringing in some three hundred wells.

In the latter part of 1931, a Fire Protection Committee was organised in the East Texas field under the sponsorship of the American Petroleum Institute. The major producers all agreed to co-operate so that, in event of a serious fire, all fire-fighting equipment in the district could be called upon for use in extinguishing the fire.

There have been no important developments of fire extinguishers or other fire-fighting devices. However, the past year has been marked by the increasing use of the Carbon-Dioxide extinguisher. This extinguisher can be used safely and very effectively on electrical fires. It is particularly suitable for gasoline plant laboratories and has been used widely, since the extinguishing agent is a gas which causes no damage to laboratory equipment and leaves no debris to be cleared UP.

Refining.

By W. J. Wilson, F.I.C., A.C.G.I. (Member).

This report makes no attempt to survey advances in oil refining generally, but has been compiled from a number of contributions supplied by authors, each of whom has direct knowledge of the progress of the industry in a particular region.

Germany (Reported by Professor Fritz Frank).

The Heckmann system of high vacuum distillation, described in last year's reports, has been further developed,[1] and has been incorporated in commercial units. The system permits of reduction to cylinder oils by indirect heating only.

Improvements have been effected in acid treatment of oils by the apparatus of the Bergedorfer Eisenwerke-Alfa Laval, in which, after intimate mixing of distillate and acid, the unused acid, sludge and refined distillate are separated centrifugally. The duration of the operation for a given quantity of oil is stated to have been considerably reduced with satisfactory results, while the plant itself is much smaller than formerly.

The separation of paraffin wax from oil by the Alfa-Laval process, in which the wax distillate is diluted with trichlor-ethylene, formed the subject of a recent article[2] in this Journal. Another method of interest, patented by the I. G. Farbenindustrie, is that of the addition of crystalline substances, such as naphthalene, to oil-wax mixtures, in which the wax is not well crystallised, in order to render the latter readily filterable.

A cracking process embodying novel features is undergoing development by the firm of Heckmann, Berlin. The principle of this process is that of cracking under pressure in three stages, at progressively higher temperatures, the products of each stage of cracking being separately fractionated. The new Pintsch process is one of vapour phase cracking.

Poland (Reported by S. Pilat, Ph.D.).

The process of separation of gasoline from natural gas by means of activated charcoal, referred to in the last report, has contributed to an increased output of gasoline, notwithstanding a falling production of natural gas. The process has been discussed by E. Reisemann.[3]

---

[1] Hoffman, *Petr. Z.*, 1931, **27**, 387.
[2] Backlund, *J. Inst. Petr. Techn.*, 1933, **19**, 1.
[3] *Petr. Z.*, 10.2.32, **28** (6), 1.

Much satisfaction is expressed with the results attained by the use of the modern distillation units which have been installed in recent years, but as the capacity of these plants represents not more than 10 per cent. of Poland's total refining capacity, there remains ample scope for further enterprise in this direction.

In the course of 1932 Mr. E. Davidson, Mr. A. Dietzius and Dr. S. Pilat were appointed by the Polish Board of Trade to carry out a complete census of the refining capacity of all the refineries in Poland.

Poland's total refining capacity was estimated to be approximately 1,000,000 tons per annum.

In the course of this enquiry there came to light some very interesting historical information, especially in regard to the old small refineries built in the sixties and seventies of the last century. A dozen or so of these works, scattered in localities on the fringe of the Carpathian Mountains, have survived until this day almost in their original condition.

RUMANIA (Reported by Ion Edeleanu, A.C.G.I., B.Sc., D.I.C.).

As was to be expected, very little development of refining took place in Rumania during 1932. In most refineries no new installations were made, and such changes as were made incorporated no novel features.

CANADA (Reported by W. W. Goulston, B.A., B.Sc.).

During the past year refining activity in Canada has increased to a considerable extent. A number of new plants were completed, several new plants are in process of erection, and a number of refineries have remodelled and extended their refining capacity. The new construction was largely the result of the protection given to refining operations by the Canadian Government's import tariffs and anti-dumping laws.[4]

As a result of the increased construction, Canada will not need to import any finished petroleum products, and may even be in the position to export refined products.[5]

The extreme winter conditions in Canada make it necessary to have either large storage capacity for crude oil and finished products or spare refinery capacity to meet the large demands of the summer months.

The Canadian market demands gasoline of high quality, and the larger companies sell gasoline having 71 octane number and high volatility. To meet this position, a number of cracking units have been installed at various refineries.

---

[4] *Oil & Gas J.*, 31.3.32, **30** (46), 64.
[5] Willson, *Oil & Gas J.*, 3.11.32, **31** (24), 8.

The crude oil production in Canada supplies only a portion of the refinery intake, the main supplies of crude oil being obtained from the Mid-Continent and Californian fields of the U.S.A. and from South America.

At the beginning of 1932 four newly built refineries were put into operation[4]:—

The Bell Refining Co., Ltd., completed a plant at Calgary, Alberta, having a capacity of 750 barrels of crude oil daily and a cracking capacity (vapour phase) of 500 barrels daily.

The Radio Refineries Inc. brought into operation a skimming plant of 1000 barrels daily capacity at Winnipeg, Manitoba.

The Sterling Oil Refineries, Ltd., commenced operating a refinery at Moose Jaw, Saskatchewan, having a daily capacity of 2000 barrels of crude oil. This refinery also has a cracking plant designed and erected by the company and having a daily capacity of 1200 barrels.

The British American Oil Co., Ltd., who have been operating a refinery at Toronto for several years, have erected a new refinery at Montreal. The main feature of the plant is a modern combination of a Winkler-Koch skimming and cracking unit having a crude oil capacity of 15,000 barrels and cracking capacity of 7000 barrels daily.[6]

During 1932 six new refineries were completed and were put into operation:—

The Simrall Refinery Corporation, Ltd., started up their refinery at Ambertsburg, Ontario,[7] in the middle of the year. The plant consists of a Foster-Wheeler topping unit with a crude oil capacity of 2500 barrels daily. Extensions to this refinery are now under way, a cracking unit being under construction to handle the heavy fractions from the topping plant.

The Seaboard Oil and Refining Co., Ltd.,[8] commenced operating their refinery at North Vancouver, British Columbia, during the summer. This is a topping plant of 3000 barrels daily capacity erected by the South Western Engineering Corporation.

Imperial Oil, Ltd.,[9] started up a new small topping plant during the summer at Fort Norman, drawing its supply of crude oil from the neighbouring Fort Norman wells. This refinery is probably the furthest north refining plant on the American Continent.

The Lion Refining Co.[10] completed in August a small skimming plant of 250 barrels daily capacity at Calgary, Alberta.

---

[6] *Oil & Gas J.*, 24.11.32, **31** (27), 28.
[7] *Oil & Gas J.*, 1.12.32, **31** (28), 28.
[8] *Refiner*, Apr., 1932, **11** (4), 76A.
[9] *World Petr.*, 1932, **3**, 482.
[10] *Refiner*, Sept., 1932, **11** (9), 52A.

The La Salle Petroleum Refiner, Ltd.,[11] completed the erection of a Foster-Wheeler topping plant in the middle of the year at East Montreal. This refinery operated on Russian crude oil shipped to Canada by the Russian Government in accordance with a barter arrangement in exchange for a cargo of aluminium.

The Shell Oil Co. of British Columbia, Ltd., completed the erection of a refinery at Vancouver, British Columbia, in December, during which month the distillation of Californian crude oil was commenced. The refinery consists of a pipe still and bubble-tower topping plant having a daily capacity of 2500 barrels of crude oil.

During the year six new refineries were under construction and are expected to be ready for operation early in 1933 :—

The Shell Oil Co. of Canada, Ltd., has under construction at East Montreal a new refinery which, it is expected, will commence operations in March, 1933. The plant consists of a combined topping and cracking Dubbs unit of the most modern design having a daily capacity of 5000 barrels of crude oil. The cracked gasoline is to be treated by the Gray process.

Hi-Way Refineries, Ltd.,[12] are constructing a small refinery at South Westminster, British Columbia, at a cost of $100,000 on a three acre site.

General Petroleums, Ltd.,[13] are building at Edmonton, Alberta, a new refinery, having a daily capacity of about 1400 barrels of crude oil at a cost of $40,000. It is proposed to expand this new refinery at an eventual cost of $400,000. The plant will treat crude oil from Montana, Texas and Pennsylvania, as well as any Alberta crude oil available.

H. C. Karels and R. E. Karels[14] are building a small skimming plant at Regina, Saskatchewan, at a cost of $25,000.

The Direct Oil Refinery, Ltd.,[15] are erecting a small refinery in Winnipeg at a cost of $30,000.

The Crown Oil Co.[16] is constructing a new refinery at Weyburn, Saskatchewan. The plant will have a daily capacity of 100 to 150 barrels.

A number of new refineries are being planned for the immediate future. The largest one is that which the Gulf Refining Co.[17] proposes to build at St. John, New Brunswick. The initial cost of the plant will be about $750,000, and provision is being made

[11] *Oil & Gas J.*, 15.12.32, **31** (30), 28.
[12] *Petr. Times*, 1933, **29**, 182.
[13] *Oil & Gas J.*, 27.10.32, **31** (23), 28.
[14] *Oil & Gas J.*, 16.6.32, **31** (4), 34.
[15] *Refiner*, Sept., 1932, **11** (9), 52A.
[16] *Oil & Gas J.*, 29.9.32, **31** (9), 34.
[17] *Petr. Times*, 1933, **29**, 252.

for expansion. The first unit will have a daily capacity of 2000 barrels of crude oil.

Among the smaller refineries which are under consideration are two to be built by the Hi-Way Refineries, Ltd.,[18] at Regina and Saskatoon; one by the Cities Service Co.[19] at Toronto; one by Asphaltic Oils, Ltd.,[20] at Winnipeg, and one by the Lloyd Refining Co., Ltd.,[21] at Port Credit, near Toronto.

A number of the established refineries are carrying out large extension programmes to increase their capacity and to improve the quality of their products.

The Northwest Stellarene Company,[22] who built a refinery at Coutts, Alberta, in July, 1931, have now replaced their old cracking unit by a full flashing type Dubbs unit of 1500 barrels daily capacity. They have also increased their boiler and tankage capacity.

Maple Leaf Petroleum, Ltd.,[23] are expanding the capacity of their refinery at Coutts, Alberta, and are installing cracking capacity.

Imperial Oil Co. have made very extensive additions and improvements to their refineries in Canada. They have spent $1,000,000 on new equipment at their refinery in Ioco, Vancouver,[24] including $150,000 on the extension of their gasoline plant.[25] They are also increasing the capacity of their refinery at Halifax, Nova Scotia.[26] At the Sarnia, Ontario, refinery a new process has been developed for the manufacture of asphalt paving mixture, and this material is being tested over a stretch of $1\frac{1}{4}$ miles of road north of Sarnia.[27] At this refinery the Goodwin process for treating cracked fuel[28] was installed. The plant has a daily capacity of 2500 barrels. The cracked fuel is treated with waste acid which causes sludge to precipitate in a form making it easy to separate by settling or filtration. This treatment leaves a stable cracked fuel which can be blended with a thinner fuel to meet the market specifications.

India (Reported by J. A. Carpenter, M.A., F.I.C.).

A certain amount of progress has been recorded by some of the companies operating in India, mostly in continuation of programmes laid down prior to the period under review.

---

[18] *Petr. Times*, 1933, **29**, 204.
[19] *Oil & Gas J.*, 9.6.32, **31** (3), 42.
[20] *Refiner*, Aug., 1932, **11** (8), 54A.
[21] *Petr. Times*, 1933, **29**, 252.
[22] *Petr. Times*, 1932, **28**, 10.
[23] *Refiner*, May, 1932, **11** (9), 60A.
[24] *Petr. Times*, 1932, **28**, 313.
[25] *Refiner*, Aug., 1932, **11** (8), 54A.
[26] *Refiner*, Nov., 1932, **11** (11), 60A.
[27] *Refiner*, Nov., 1932, **11** (11), 60A.
[28] *Refiner*, Oct., 1932, **11** (10), 508.

Gasoline recovery from natural gas in the Burma fields has been increased with the aid of new Braun absorption plants at Yenangyoung and Singu; the recovered gasoline is still pumped through the main pipe line to the refinery after blending.

At the Syriam refinery of the Burmah Oil Company, near Rangoon, the manufacture of petroleum asphalts by means of the air blowing of heavy aromatic[39] extracts has been commenced, and is proceeding as a routine operation, although at present only on a small scale.

Burning of weathered acid sludge as fuel in admixture with equal quantities of Dubbs coke has been effected on a substantial scale.

The manufacture of specially extracted anti-malarial oils has been developed. Collaboration in research on anti-malarial work has been carried out both at Syriam and at Digboi (Upper Assam), with the India Branch of the Ross Institute and other leading medical authorities.

At the Seikkyi refinery of the Indo-Burma Petroleum Company, near Rangoon, some of the older fractionating equipment has been replaced by a bubble tower designed by Messrs. Winkler-Koch and manufactured by Messrs. Craig, of Paisley, Scotland; this is mainly designed to fractionate the lighter ends of the crude oil.

At the Digboi refinery of the Assam Oil Company an Edeleanu plant embodying latest improvements has been installed and put into commission. In this plant special control instruments are fitted, while sulphur dioxide can be taken into use through direct absorption in the charging stocks.

TRINIDAD (Reported by A. P. Catherall, B.Sc., M.I.Min.E., A.M.Inst.M.M.).

A new distillation plant, of the Trumble type, is under construction at the Point Fortin refinery of the United British Co. Its capacity is rated at 1000 tons daily. A topping plant of 1000 barrels capacity is being constructed by Kern Trinidad Oilfields, Ltd. Both these plants are designed to produce light distillates, gas oil and residual fuel oil.

PERU (Reported by J. Wilfred Burford, M.I.Min.E., M.Inst.E.E.).

The only petroleum refining of any importance in Peru is that carried out at Talara by the International Petroleum Co., Ltd., who have a modern refinery capable of running 16,000 barrels per day of crude oil.

The crude oil processed at Talara Refinery is gathered from wells adjacent to the Refinery and is of two classes, a wax bearing

[39] E.P. 362,580, 364,666; *J. Inst. Petr. Techn.*, 1932, **18**, 57A, 92A.

crude of approximately 38·3° A.P.I. and a non-wax bearing crude of approximately 35·1° A.P.I.

The former is run primarily for gasoline, refined oil and fuel oil, the latter primarily for lubricating oils with the attendant production of gasoline and fuel oil.

The high cold test crude is processed in a continuous battery of shell stills equipped with a conventional type of fractionating bubble tower and heat exchange equipment, overhead cuts being made for aviation gasoline, motor gasoline and refined oil, while the reduced crude residue of 28° A.P.I. is used either as fuel oil or as stock for the cracking units. All natural gasolines receive a lye wash and sodium plumbite treatment, while the refined oil receives a light acid treatment followed by lye and clay treatments to finish.

In the cracking units, which are of the tube and tank type, the reduced crude residue is cracked to yield light distillate, Diesel oils, bunker fuel oil and a very small amount of coke. The distillate is redistilled in a continuous atmospheric shell still equipped with a fractionating bubble tower, the overhead product being clay treated and finished with a plumbite solution before blending with the production of natural gasoline from the atmospheric crude stills.

The high and low pressure gas produced at the cracking units, together with the gas produced at the crude batteries, passes through an absorption plant; the production of light gasoline from this source is lead lye treated and blended with the heavier natural and cracked fractions in accordance with gasoline specifications. This absorption gasoline production is augmented by the absorption product produced in the gasoline recovery plants in the oil producing fields, where gas from the oil wells is similarly processed.

The low cold test crude is processed in a battery of atmospheric shell stills to give a 19° A.P.I. residue, overhead cuts of gasoline and gas oil being made. This residue is then charged to a continuous vacuum distillation unit, the products from which are gas oil, light and heavy lubricating distillates, cylinder stock and a pitch residue which is fluxed with fuel oil. The light lubricating distillate receives a hot lye treatment, and is then redistilled in a batch vacuum still and fractionated into cuts corresponding to the lighter grades of lubricating oils. These overhead cuts are then treated with sulphuric acid, and finished with a lye wash. The heavy lubricating distillate is not hot lye treated, but is redistilled in the batch vacuum still and fractionated into cuts corresponding to the heavier grades of lubricating oils, each individual cut being treated with sulphuric acid and finished with a clay treatment by the "contact" process.

The Cracking Art in 1932.*

By GUSTAV EGLOFF, Ph.D., M.A., M.Am.Inst.Chem.E., M.Am.Chem.Soc. (Member), and BADONA L. LEVINSON.

I. INTRODUCTION.

PROGRESS in the art of cracking during the past year has been especially marked by the cracking of straight-run gasolines and naphthas which are not suitable for the modern high-compression automobile engine. Demand for higher octane ratings of motor fuels has continued to be emphasised during the year.

Daily cracking capacity in United States refineries increased[1] from 1,844,609 barrels in 1931 to 1,954,550 barrels in 1932.

Europe is showing increased interest in the cracking process as an aid to her petroleum industries. Truesdell[2] points out the necessity for European cracking expansion because of demand for more and better gasoline. He graphs the increasing use of motor vehicles in countries other than the United States, and states that indications are that increased interest in motor vehicles will bring a development in refining similar to that in the United States.

The same relation of the refining to the motor industry is emphasised by Burgart and Graetz[3] in discussing the development of refining in France. They point out the great significance of cracking as well as the need for co-operation and close study of American methods.

Great Britain's refining industry[4] shows increased cracking with decreased crude oil throughput for the year. Eglit[5] criticises the cracking development in Russia for its failure to make wider use of modern cracking.

The demand for high octane numbers continues to rise, and anti-knock quality remains one of the chief properties of gasoline. Improvements in the cracking process are keeping pace with the increasing octane requirements. Egloff[6] describes the march of octane demand in the United States from east and west toward the Mid-Continent areas. The answer to this demand is cracked motor fuel to run the automobile engines of ever increasing compression ratios. The table of compression ratios of automobile

* This report covers publications from November 1, 1931, to November 1, 1932.

[1] *Oil & Gas J.*, 31.3.32, **30** (46), 61.
[2] *World Petr.*, 1932, **3**, 279.
[3] *Bull. soc. encour. ind. nat.*, 1932, 30.
[4] *Petr. Times*, 1932, **28**, 147.
[5] *World Petr.*, 1932, **3**, 237.
[6] *Oil & Gas J.*, 5.5.32, **30** (51), 38; *World Petr.*, 1932, **3**, 39.

motors since 1924 aptly illustrates the reason for the demand for higher octane numbers :—

Compression Ratio.

(*Based on Number of Models Offered.*)

Year.	Less than 4·5 to 1 per cent.	4·5–5·0 to 1 per cent.	5·0 to 1 and over per cent.
1924 ..	57·7 ..	38·8 ..	3·5
1925 ..	42·1 ..	53·9 ..	4·0
1926 ..	33·3 ..	63·6 ..	3·1
1927 ..	28·9 ..	55·3 ..	15·8
1928 ..	12·0 ..	67·0 ..	21·0
1929 ..	8·0 ..	37·0 ..	55·0
1930 ..	2·1 ..	31·3 ..	66·6
1931 ..	1·3 ..	26·7 ..	72·0
1932 ..	2·8 ..	5·7 ..	91·5

The same octane race is the subject of an article by Ziegenhain,[7] who describes a concentrated effort toward improved cracking in Middle West refineries to produce a high anti-knock product. He presents comparative data on gasolines from fourteen refineries over a period of 18 months, which show considerable improvement in anti-knock.

Reid[8] also emphasises the definite trend of the industry toward more extensive utilisation of the cracking process. He cites a few reasons for " the prevailing marked activity of construction of cracking facilities in the refining industry." These, he claims, are competitive conditions within the industry, increased motor compression ratios, insistence of motorists on high anti-knock fuels, and the raising of ethyl standard from 74 to 78 octane number.

He also[9] emphasises the downward trend of straight-run gasoline to be replaced by cracked motor fuel. He states : " The refiner not possessed of cracking facilities will find it increasingly difficult to compete with his more efficient neighbours and to market his relatively low anti-knock rating motor fuels."

Remodelling and improvement of old cracking installations has been going on at a considerable rate, and such plants show increased yields, improved products and decreased losses. Foster[10] reports the conclusion of a study of cracking and " reforming " by Mid-Continent refiners. They are reported to have found that low losses and high yields may be best obtained by cracking different fractions under individual optimum operating conditions. They consider it more profitable to crack heavy naphtha than to make a low-grade straight-run gasoline. It is estimated that the cracking

[7] *Oil & Gas J.*, 24.12.31, **30** (32), 15 ; *J. Inst. Petr. Techn.*, 1932, **18**, 51A ; *Oil & Gas J.*, 10.3.32, **30** (43), 14.
[8] *Oil Weekly*, 11.4.32, **65** (4), 13.
[9] *Refiner*, 1932, **11**, 274 ; *J. Inst. Petr. Techn.*, 1932, **18**, 223A.
[10] *Nat. Petr. News*, 1932, **24** (24), 32.

capacity needed in Oklahoma and Texas to replace obsolescent equipment is 125,000 barrels per day.

Egloff and Nelson[11] say: "Speaking broadly, cracking, when the proper principles are employed, can produce economically, from any charging stocks, gasoline which suits the modern automobile engine." In fact, cracking is doing this to-day with stocks which include crude oils, heavy residues, light gravity fuel and gas oils, kerosine, naphtha and gasoline, and blends of these. They state that "cracking operations, to be profitable, must be conducted in accordance with economic laws."

The growing place of synthesis in the oil industry has been surveyed by Egloff.[12] He finds that modern industry demands synthetic oils for its highly exacting machines since gasoline, lubricating oil, and fuel oils, as produced by nature, are no longer suitable. Motor fuel quality, in particular, is required and cracked gasoline is the synthetic product which best solves the problem. It is superior to its straight-run counterpart and brings a premium price based on its octane number. The cracking process as the dominant force for synthesis in the oil industry is yielding high quality, synthetic fuel oils, gas, coke, lubricating oils, road oils and asphalts, as well as the premium gasoline already mentioned.

In Russia it has been reported by Dunaev[13] that one metric ton of gasoline costs 14·53 roubles as compared with 10·89 roubles in the United States. Levshin[14] reports the cost of a gallon of cracked gasoline in Grozny as produced from various cracking units:—

Cracking unit.	Kopeks per gallon.
Dubbs	5·5754
Cross	5·5786
Winkler-Koch	6·5914
Jenkins	10·3384

The valuable co-products of the cracking process have grown in number and in quality, including coke and asphalt, special fuel oils, lubricating oils, resins, insecticides, alcohols and solvents, as well as miscellaneous hydrocarbons and derivatives for use in the chemical industries.

Efficient operation of plant equipment has been receiving profitable study while cracking apparatus itself continues to be improved, yielding greater amounts of product of better and more closely controlled quality. Means for controlling conditions in

[11] *Petr. Times*, 1932, **28**, 245.
[12] *Petr. Times*, 1932, **28**, 69.
[13] *Neft. Khoz.*, 1932, **22**, 69; *Chem. Abs.*, 1932, **26**, 4454.
[14] *Groznenskii Neftyanik*, 1931, **1** (11–12), 51; *Chem. Abs.*, 1932, **26**, 4705.

the cracking plant and methods of protection against corrosion have continued to develop during 1932.

The terms " liquid-vapour phase " and " vapour-phase " cracking are used in this report with no thought that they are strictly accurate terms describing cracking operations, but rather as a convenient basis for rough classification.

II. The Cracking Reaction.

A number of studies on the qualitative and quantitative factors of the cracking reaction have appeared during the past year. Weir and Eaton[15] determined the total heat content of five oils, in liquid and in vapour phase, at temperatures up to 1004° F. (540° C.). Four of the oils, of Mid-Continent origin, ranged in gravity from 20° to 58° A.P.I., and the fifth was a highly refractory cracked gas-oil. The last oil was compared to the others as a gauge of the variation in total heat content which may occur with oils of different constitution. The relationship recommended for calculating the heat content of Mid-Continent oils is :—

$$H=(15d-26)-(0{\cdot}465d-0{\cdot}811)t+0{\cdot}000290t^2,$$

where H=total heat content above 32° F., B.Th.U./lb. of oil ;
t=temperature ° F. ;
d=specific gravity of material as liquid at 60° F.

The corresponding heat content vs. temperature relationship for Mid-Continent oil vapours is :—

$$H=(215-87d)+(0{\cdot}415-0{\cdot}104d)t+(0{\cdot}000310-0{\cdot}000078d)t^2.$$

Work on the reaction-velocity constants of cracking has been reported by Geniesse and Reuter,[16] who cracked a " Mid-Continent type gas-oil " and several naphthas at atmospheric pressure. The rate of reaction for gas oil is reported to double for an increment of 14° at 450° C., and an increment of 21° at 600° C. ; while its activation energy is of the order of 53,400 calories per gram mole. Pressure cracked naphthas were found to decompose more readily than straight-run naphthas, but both types require the same activation energy as gas oil. Comparison of petroleum fractions with pure hydrocarbons showed that the rates of decomposition increase with increasing molecular weight, while the activation energies for decomposition are the same for petroleum fractions as for all hydrocarbons.

Using straight-run gasoline from Pennsylvania crude, Cassar[17] has made a study of vapour phase cracking. The apparatus used was

[15] *Ind. Eng. Chem.*, 1932, **24**, 211 ; *J. Inst. Petr. Techn.*, 1932, **18**, 135A.
[16] *Ind. Eng. Chem.*, 1932, **24**, 219 ; *J. Inst. Petr. Techn.*, 1932, **18**, 131A.
[17] *Ind. Eng. Chem.*, 1932, **24**, 802 ; *J. Inst. Petr. Techn.*, 1932, **18**, 317A.

operated at 500 to 700° C. With constant feed rate (600 ml. per hr.) it was found that the gas evolved increased directly as a linear function of the temperature. The equation offered for the reaction was :—

$$G = 2{\cdot}38\ (T-480),$$

where G equals volume of gas per unit volume charge and T equals temperature in ° C. The rate of reaction was observed to double for every 70° between 500 and 700° C. Since the gas formed per unit time, in constant temperature experiments at 600° C., was proportional to the quantity of gas already formed, the author concluded that the reaction is auto-catalytic and that a partially gasified stock should therefore crack more readily.

A series of formulæ have been developed by Luts[18] for the prediction of cracked gasoline yields based on the thermal properties of the charging stock.

Obryadchikov[19] has calculated the latent heat of the cracking reaction under various conditions with particular concern as to its relation to composition of the charge, yield of gasoline, degree of cracking and temperature. He concludes that cracking heavier oils requires more heat than light oils ; that the heat of reaction decreases with increasing yields of gasoline, and that the reactions at the end of the cracking are predominantly exothermic except where there is " very heavy cracking." The influence of temperature upon the latent heat of the cracking reaction is regarded by Obryadchikov as insignificant. The same author[20] had reported on this subject somewhat earlier, drawing similar conclusions and, in addition, indicating that the volume of the products of vapour-phase cracking cannot be calculated by the gas laws, but requires an additional co-efficient of approximately three.

Another comparison of the results of cracking different charging stocks is reported by Tilicheev and Feigin,[21] who cracked ethylene and paraffin hydrocarbons at 425° C. They conclude that ethylene hydrocarbons are more rapidly decomposed than paraffins, the difference being least for compounds of high molecular weight. Volf and Shevlyakov[22] investigated the influence of a number of factors upon the non-residuum type cracking of a " semi-asphalt " stock, Surakhani and Balakhani fuel oil, and several cracked fuel oils. Their studies included the effects of amount of oil in the still

[18] *Oil & Gas J.*, 29.9.32, **31** (19), 20 ; *J. Inst. Petr. Techn.*, 1932, **18**, 442A.
[19] *Refiner*, 1932, **11**, 34.
[20] " Rep. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 67 ; *Chem. Abs.*, 1932, **26**, 1104.
[21] " Rep. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 267 ; *Chem. Abs.*, 1932, **26**, 1105.
[22] *Azer. Neft. Khoz.*, 1931 (11–12), 80 ; *Chem. Abs.*, 1932, **26**, 4705.

and its size, effect of velocity of distillation, and the qualitative composition of the distillates at different stages.

Data on the molecular weight, specific gravity, boiling point, temperature of "molecular instability" and pressure at that temperature were tabulated by Burke and Melton[23] for a number of hydrocarbons from pentane to nonacosane. These data were applied, theoretically, to the problem of contacting a heavy petroleum product with natural gas to produce gasoline.

A series of articles by Trusty[24] treats the problem of the selection of cracking stocks from several points of view. Examination of the cracking characteristics of the individual hydrocarbon groups present in petroleum oils indicated that their percentages definitely affect the "crackability" of the stock. "Olefins and paraffins without coke are the products of primary cracking of paraffin hydrocarbons. At higher temperatures or with longer time, secondary, tertiary and further reactions occur in which coke is formed." In short, the more paraffinic the stock, the less coke is formed. According to Trusty, the formation of olefins is rapid with rise of cracking temperature. The naphthenes, he states, are more stable to heat than the paraffins and retain their ring structure to a great degree through the cracking cycle. "Aromatic cracking stocks are the most refractory, both from the standpoint of ease of cracking and amount of gasoline formed, and are also greater coke formers than other stock." Laboratory examination of a cracking stock, indicating its tar number, aniline number and distillation characteristics, is considered of value in determining its coke-forming properties under cracking conditions. A low tar number indicates low coke formation.

In selecting a cracking stock, Trusty recommends keeping in mind that the rate of cracking is a function of the boiling range, and the more closely fractionated stock cracks "more efficiently." "The ideal cracking stock is a heavy closely fractionated gas oil fraction with a low carbon residue, low tar number and low aniline number."

A number of investigators have interested themselves in the various characteristics of cracked products. A study of the composition of fractions of a "highly cracked gasoline" before and after heating for six hours under 68 atmospheres at 300° C. was made by Payne and Lowy.[25] The percentage of unsaturated hydrocarbons was decreased by heat and pressure treatment in all the fractions isolated. The percentage of naphthenes in the whole

[23] *Oil & Gas J.*, 7.7.32, **31** (7), 29; *J. Inst. Petr. Techn.*, 1932, **18**, 356A.
[24] *Oil & Gas J.*, 1931, **30** (21), 22; *Refiner*, 1932, **11**, 48, 335, 474, 519; *J. Inst. Petr. Techn.*, 1932, **18**, 119A, 274A, 443A; 1933, **19**, 26A.
[25] *Ind. Eng. Chem.*, 1932, **24**, 432; *J. Inst. Petr. Techn.*, 1932, **18**, 163A.

distillate up to 201·5° C. was increased by the treatment. Benzene and toluene were identified in selected fractions. In general, the proportion of unsaturated hydrocarbons decreased with increasing boiling point, while the paraffins decreased and naphthenes and aromatics increased.

Nunn[26] claimed that, provided the cracking charge is constant as to base, cracked gasolines may be evaluated for knock-rating by use of the aniline test.

Panyutin and Milovidova[27] determined the mercury and thiocyanate numbers of several liquid-vapour and vapour cracked gasolines. The action of thiocyanate seemed to be somewhat different from that of Hg acetate upon the olefins in cracked gasoline. The physico-chemical properties of cracked and straight-run gasolines were reported by Panyutin and Irisov[28] who determined vapour tension (Sorrel method), Engler distillation and chemical composition. They also measured the dynamic volatility of the gasolines. Graphs showing the specific gravity and aniline points of narrow cuts of cracked gasoline have been offered by Bespolov,[29] to indicate the distribution of hydrocarbons. Birch and Scott[30] used the addition of maleic anhydride to form crystalline acid anhydrides in the determination of diolefins in the lower fractions of vapour cracked gasolines. Butadiene, piperylene, isoprene and cyclopentadiene were readily separated. .

A number of treated cracked gasolines and mixtures with straight-run motor fuels were tested in an automobile engine by Petrov and Kolosov.[31] They conclude that cracked gasolines and mixtures deposit a hard shiny carbon in a thinner layer and of different quality from that formed with a straight-run product.

Goodwin[32] puts in an emphatic word for the value of cracked residuum as a co-product rather than a by-product of cracked gasoline production. He suggests that the refiner use chemical and mechanical means to produce a "stable" cracked fuel oil, free from solids. Such a fuel from cracked residuum would have physical properties superior to an uncracked one. The characteristics of cracked fuel oil from the processing of many stocks have been shown by Egloff and Nelson in their series of articles.

[26] *Refiner*, 1932, **11**, 434; *J. Inst. Petr. Techn.*, 1932, **18**, 381A.
[27] Collection Repts. Motor Fuel Research, U.S.S.R., *Trans. Sci. Automobile-Tractor Inst.*, 1931, Issue **21**, 33; *Chem. Abs.*, 1932, **26**, 4457.
[28] Collection Repts. Motor Fuel Research, U.S.S.R., *Trans. Sci. Automobile-Tractor Inst.*, 1931, Issue **21**, 3; *Chem. Abs.* 1932, **26**, 2855.
[29] "Rep. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 323; *Brit. Chem. Abs.–B*, 1932, 456.
[30] *Ind. Eng. Chem.*, 1932, **24**, 49; *J. Inst. Petr. Techn.*, 1932, **18**, 103A.
[31] Collection Repts. Motor Fuel Research, U.S.S.R., *Trans. Sci. Automobile-Tractor Inst.*, 1931, Issue **21**, 19; *Chem. Abs.*, 1932, **26**, 4457.
[32] *Refiner* 1932, **11**, 508; *J. Inst. Petr. Techn.*, 1933, **19**, 1A.

Superiority of cracked fuel over the straight-run product has been indicated by Egloff[33] in the following points :—

"1. Cracked fuel is a manufactured product, and can be made substantially the same irrespective of the original charging stock. Straight-run fuels are residues and vary with the crude, the type of operation, etc.

"2. Cracked fuels being heavier than straight-run fuels (4–10° A.P.I. vs. 12–24° A.P.I.) contain, on an average, 10 per cent. more heating value per gallon.

"3. Cracked fuels have lower cold test and therefore will flow more freely in cold weather.

"4. Cracked fuels have lower viscosity and therefore require less steam or less power for atomisation.

"5. Cracked fuels have a flatter viscosity-temperature curve at temperatures above 120° F. This means steadier operation with slight variations of oil temperature as it affects the viscosity, and therefore the amount of oil passing through a given valve setting.

"6. Cracked fuels are also used as a blending material for natural fuel oils."

III. Liquid Vapour-Phase Cracking.

(*a*) *Non-Catalytic.*—The range of charging stocks for cracking has expanded until present-day units process every type of oil from the lightest gasoline and naphthas to the heaviest and most refractory residues, as well as all types of crude oils.

Goldtrap[34] found that "good yields" of high anti-knock cracked gasolines could be obtained by processing straight-run gasolines and heavy naphthas, and he describes three types of plant which may be used for that purpose. Results obtained with Pennsylvania gasoline and heavy naphtha raised the octane number from 40 and 30, respectively, to 76 in both cases with yields of 84 per cent. gasoline, 5 per cent. residue, and 11 per cent. gas and loss. Two points are discussed : "(1) As the pressure is increased for a given yield, octane number increases with pressure ; (2) at a given pressure, octane number is increased at the expense of yield."

A Dubbs cracking plant at Langerbrugge, Belgium, processes gas oil and low temperature coal tar. A Rumanian gas oil, specific gravity 0·860, was reported[35] cracked under a pressure of 16 kg/cm^2 to yield 60–65 per cent. of excellent anti-knock gasoline. In the same unit, a heavy tar from low temperature

[33] *Petr. Times*, 1932, **28**, 91.
[34] *Oil & Gas J.*, 14.4.32, **30** (48), 22 ; *J. Inst. Petr. Techn.*, 1932, **18**, 255A.
[35] *Rev. Petr.*, 1931 (452), 1639.

distillation of coal, specific gravity 1·064, was cracked to produce 40 per cent. of high anti-knock gasoline.

Stemart[36] describes this same cracking plant and, in discussion, adjudges the Dubbs installation best for European use because of its flexibility.

A cracking plant in France[37] uses the Dubbs process to crack imported East Texas fuel oil, yielding 50 per cent. pressure distillate, 46 per cent. cracked fuel oil, with 4 per cent. gas and loss. The cracked gasoline of end-point 190-200° C. has excellent anti-knock rating. In Germany a Dubbs plant at Hannover operates under 18 atm. pressure at 500° C., processing Nienhagen and Edessa topped crude oil to yield 78 per cent. pressure distillate. Two Dubbs units in Assam[38] treat a residuum charging stock of specific gravity 0·946, flash point 425° F., and set point 131° F. The cracking process here is operated to produce gasoline and coke with yields of 46·0 per cent. of gasoline, 11 per cent. Diesel oil and 36 per cent. coke.

A survey of cracking as it has grown in Rumania in the past few years[39] presents an interesting picture of steady advance in yields of valuable products, particularly from heavy, refractory stocks. Residues which, five years ago, yielded 48 per cent. of pressure distillate, 12 per cent. residuum, 22 per cent. coke and 18 per cent. gas and loss, are now being converted to 40 per cent. of pressure distillate, 50 per cent. of valuable cracked fuel oil, and 10 per cent. of gas and loss, with no coke formation. Paraffin distillate, having a congealing temperature of 37° C., is being cracked in a similar unit by either the "full flashing" or the non-residuum or coking method of operation. By the latter method the paraffin distillate yields 69 per cent. of pressure distillate and 16 per cent. of coke; while the same charge will produce 52 per cent. of pressure distillate and 36 per cent. of cracked fuel oil under flashing conditions.

A 59-day run in a new Dubbs unit in Pennsylvania has been described by Nelson and Alberding.[40] The cracking unit processes 798 barrels of Pennsylvania gas oil per day to yield 65–72 per cent. of 400° F. end-point gasoline of 70–74 octane number. Another Pennsylvania plant using the same process[41] produced 66–70 per cent. of 375–400° F. end-point gasoline of 68–72 octane number from Bradford, Pennsylvania, gas oil.

---

[36] *Chim. et Ind.*, 1931, **26**, 521.
[37] *Rev. Petr.*, 1932 (474), 559.
[38] *Petr. Times*, 1932, **27**, 525.
[39] *Rev. Petr.*, 1932 (485), 899.
[40] *Petr. Z.*, 1932, **28** (3), 7.
[41] *Petr. Eng.*, 1932, **3** (61), 52.

The series of reports begun in 1931 on cracking various oils from fields over the world has had a number of interesting additions this year by Egloff and Nelson.[42] The charging stocks vary, not only in source, but in type, ranging from straight-run gasoline, naphtha and kerosine to topped crude, and, frequently, the whole crude oil as it comes from the ground. The cracking conditions were about 350 lb. per square inch and 950° F., and the yields of cracked gasolines, based on the charging stock, as well as the octane numbers of the cracked products, may be noted from the following table :—

Charging Stock.	Source.	Gasoline per cent. of Charge.	Octane Number.
Crude oil	Czechoslovakia	53·1 ..	89
Crude oil	Santa Fé Springs, Cal. ..	63·6 ..	77
Crude oil	Kettleman Hills, Cal. ..	74·3 ..	75
Crude oil	Lost Soldier, Wyoming ..	60·0 ..	79
Topped crude ..	Kettleman Hills, Cal. ..	58·6 ..	80
Gas oil	Pennsylvania	70·5 ..	75
Kerosine	Pennsylvania	84·4 ..	76
Naphtha	Mid-Continent	72–80 ..	81–91
Naphtha	Pennsylvania	83·7 ..	74
Gasoline	Pennsylvania	81·2 ..	75
Gasoline	Mid-Continent	73–81 ..	70–75

An oil refinery recently completed in France is described by Trival.[43] The cracking equipment is of two kinds : a Cross unit of 2500 barrel capacity for cracking kerosine and gas oil, and a Dubbs unit of the same capacity for cracking " the bottoms from the topping operation."

Russia has included cracking in her industrial expansion, and the results have been reported in the Soviet Press. A quotation from part of this report[44] indicates operation of three cracking plants at Grozny. A Winkler-Koch unit is described by Kalita[45] who indicates advantages and disadvantages of the unit and quotes the yields of products obtained. There are a number of these units in Russia.[46]

According to Ziegenhain[47] a Winkler-Koch unit in Oklahoma combines liquid-vapour phase cracking and naphtha " reforming " to obtain 70 per cent. of 400° F. end-point gasoline of 67 octane number from the crude oil. He indicates that the 44° A.P.I. gravity crude is topped, part of the tops being used as straight-run

[42] *Oil & Gas J.*, 10.12.31, **30** (30), 22 ; 7.1.32, **30** (34), 22 ; 14.1.32, **30** (35), 18 ; 31.3.32. **30** (46), 75 ; 20.10.32, **31** (22), 42 ; *J. Inst. Petr. Techn.*, 1932, **18**, 45A, 63A, 80A, 207A, 461A ; *Petr. Times*, 1932, **27**, 145.
[43] *Refiner*, 1932, **11**, 399.
[44] *Erdöl u. Teer*, 1932, **8**, 298.
[45] *Groznenskii Neftyanik*, 1931, **1** (8–10), 82 ; *Chem. Abs.*, 1932, **26**, 1104.
[46] *Petr. Times*, 1932, **27**, 172 ; *Rev. Petr.*, 1932 (465), 293.
[47] *Oil & Gas J.*, 11.8.32, **31** (12), 9 ; *J. Inst. Petr. Techn.*, 1932, **18**, 377A.

gasoline, while the remaining naphtha and kerosine are cracked in the "reforming unit," the topped crude being processed in the "cracking unit."

Tilicheev[48] carried out some experiments on Grozny mixed-base fuel and found that, cracked under non-residuum operation, it yielded 52–53 per cent. of gasoline in addition to 26 per cent. coke and 21 per cent. gas and loss. The same experimenter[49] reports non-residuum cracking of Surakhani fuel oil, which yields 54 per cent. of gasoline, 20 per cent. coke, and 26 per cent. gas plus loss.

The Carburol system of cracking, according to *Erdöl u. Teer*,[50] is being used in the Belgian Congo to produce gasoline.

(*b*) *Catalytic.*—The use of aluminium chloride as a catalyst in the petroleum industry is discussed in detail by Dubrov.[51] He contends that cracking in the presence of aluminium chloride is accompanied by hydrogenation of the hydrocarbons. Polymerisation and carbonisation, however, occurring simultaneously with the hydrogenation, limit the formation of light products to 70 per cent. of the original stock. The experimenter states that a maximum of 10 per cent. aluminium chloride is suitable for cracking, while high temperatures should be avoided and super-atmospheric pressures are beneficial. The gasoline thus obtained from Surakhani fuel oil contained 5·28 per cent. aromatics, 41·52 per cent. naphthenes, and 38·71 per cent. paraffins. Balakhani fuel yielded 60 per cent. naphtha; Ramani fuel 50–65 per cent.; Grozny mixed-base fuel almost none; and cracked residues up to 19 per cent. of gasoline.

IV. Vapour-Phase Cracking.

Vapour-phase cracking continues to be the subject of experiment. Ginzburg[52] has described a "true vapour-phase cracking" process.

Pratt[53] has published a description of vapour-phase cracking.

Gyro vapour-phase cracking has been described by Holland[54] to the effect that it operates at low pressure and temperature of about 1100° F. It is reported that all grades of charging stocks, including topped crude and heavy naphtha, can be converted into high octane gasoline. This vapour-phase installation, it is stated, may be operated for the production of fuel oil or coke, and "by careful regulation of temperature and time of reaction the

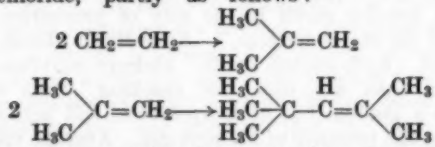
[48] "Repts. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 209; *Chem. Abs.*, 1932, **26**, 1104.
[49] "Repts. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 240; *Chem. Abs.*, 1932, **26**, 1105.
[50] 1932, **8**, 300.
[51] *Neft. Khoz.*, 1932, **22**, 19; *Chem. Abs.*, 1932, **26**, 2853.
[52] *Azer. Neft. Khoz.*, 1932 (2), 21; *Chem. Abs.*, 1932, **26**, 2855.
[53] *Refiner*, 1932, **11**, 244; *J. Inst. Petr. Techn.*, 1932, **18**, 181A.
[54] *Oil & Gas J.*, 4.2.32, **30** (38), 18; *J. Inst. Petr. Techn.*, 1932, **18**, 132A.

yield of fixed gas has been reduced to about double that from liquid-phase cracking, but the extra gas is made at the expense of fuel rather than gasoline output."

Korovatskii[55] used a kerosine distillate from cracked oil as charging stock for vapour-phase cracking. The 30 per cent. yield of cracked gasoline contained 26 per cent. aromatics and had an iodine number of 142. The temperature of cracking was 535° C. The cracked gases, specific gravity 1·2, contained 23·3 per cent. methane and hydrogen, 30·9 per cent. ethane and ethylene, 27·9 per cent. propane and propylene, 12·0 per cent. butane and butylene, 5·9 per cent. pentane, amylene and higher hydrocarbons, 0·1 per cent. carbon dioxide, 1·9 per cent. oxygen, 29·1 per cent. unsaturated compounds, 0·3 per cent. carbon monoxide, and 2·5 per cent. hydrogen.

East Texas crude oil as a cracking stock under vapour-phase operation has been the subject of experiments by Trusty and Holder.[56] They distilled ten fractions from East Texas crude, ranging from heavy naphtha to heavy gas oil and cracked each fraction separately under less than 1 lb. gauge pressure at 1080° F. The anti-knock value decreased as the heavier fractions were cracked. The knock rating of the gasoline from a paraffin fraction was poorer than that from a naphthenic one.

The preparation of a high anti-knock gasoline from the gases produced by vapour-phase cracking is the subject of an article by Petrov.[57] He concludes that the heat condensation of olefins in cracked gases proceeds at atmospheric pressure, in the presence of zinc chloride, partly as follows :—



The high molecular weight olefins are then cracked, on further heating, forming diolefins and aromatics.

The gases from vapour-phase cracking of oil also interested Markovich and Pigulevski,[58] who subjected them to isothermal distillation. Unsaturates were separated and analysed by the use of various concentrations of sulphuric acid. The same authors[59] report the composition of the gaseous products from the vapour-phase cracking of a Russian crude oil.

[55] *Neft. Khoz.*, 1932, **22**, 217 ; *Chem. Abs.*, 1932, **26**, 4456.
[56] *Refiner*, 1932, **11**, 269 ; *J. Inst. Petr. Techn.*, **18**, 223A.
[57] *Neft. Khoz.*, 1932, **22** ; *Chem. Abs.*, 1932, **26**, 4455.
[58] *Refiner*, 1932, **11**, 256, 303 ; *J. Inst. Petr. Techn.*, 1932, **18**, 159A, 222A.
[59] *Refiner*, 1932, **11**, 348 ; *J. Inst. Petr. Techn.*, 1932, **18**, 275A.

V. Combination Liquid-Vapour and Vapour-Phase Cracking.

In a unit combining the use of liquid-vapour phase and vapour-phase cracking, Ginzburg[60] describes the course of oil flow through the plant. "Naphtha is pumped through the low-pressure coil together with cracked naphtha from the stripper. The mixture is heated in the coil to 575° C. at 20 atmospheres and then enters the evaporator and bubble tower. The condensate from the bubble tower is passed with straight-run gas oil through the liquid-phase, high-pressure cracking coil. . . . In the vapour-phase cracking unit cold straight-run naphtha and cracked naphtha from the stripper, the mixture having a temperature of 185° C., are cracked at 570° C. and 160–200 lb. pressure. . . . In a modification of vapour-phase cracking, light fuel oil is passed into the lower end of the evaporator, and the cracked gas oil is withdrawn from the bottom while vapours are passed into the cracking tower. Vapours from the quenching tower enter the bubble tower. The quenching tower is flashed with gas oil. The condensate collecting in the bubble tower is passed through the cracking coil, while some of it is added to the fuel oil charging stock."

VI. Cracking with Oxidation.

The effects of oxygen, coincident with or in relation to cracking, have long been of interest to the oil man. Beall[61] cites a number of references pertaining to cracking in the presence of oxygen. Most of these methods, he claims, "are the result of attempts to supply heat by means of restricted internal combustion of portions of the hydrocarbon material undergoing treatment. Aside from this, certain benefits result in the way of prevention of carbon deposition of the metal surfaces." According to Beall, heavy oils admixed with "hydrocarbon oxide" undergo conversion at lower temperatures than are usual for cracking. Such a mixture, subjected to a gradual rise of temperature, will undergo gradual conversion in the presence of an inert gas. Average volatility and critical temperature will be lowered until vapour phase is reached, regardless of pressure, and the temperature may then be raised to that of maximum conversion. "For the production of motor fuel, this will be around 1200 lb. or higher and 785° F. or higher, depending upon the characteristics of the mixture and the amount of conversion desired." Beall's reasons for advocating the use of "hydrocarbon oxides"—produced from natural gas—in the cracking reaction are, chiefly, the small tendency to deposit carbon, especially in vapour phase under pressure, and reduction in the gaseous products ordinarily produced in cracking. He

[60] *Azer. Neft. Khoz.*, 1931 (11–12), 68; *Chem. Abs.*, 1932, **26**, 4704.
[61] *Refiner*, 1932, **11**, 390, 422; *J. Inst. Petr. Techn.*, 1932, **18**, 299A, 388A.

concludes that "the conversion into motor fuel is benefited by the admixture of hydrocarbon oxide."

Air oxidation and cracking of straight-run Pennsylvania naphtha have been compared by Schultz and White,[62] who have calculated rates and velocity constants of both reactions and correlated the yield of treated naphtha and quantity of gas formed in the two processes with improvements in knock rating. The reactions of the naphtha in the presence of oxygen appear similar, in overall effect as indicated by knock rating, to those in its absence. The rate of reaction with air below 790° C. is more rapid than cracking. The experimenters conclude that "the oxidation process may be considered, from one standpoint, as a method of accelerating reaction rate at lower temperatures. Time, temperature and oxygen concentration appear to affect reaction with air and to increase anti-knock value, while material of the tube and extent of surface seem to have little effect."

VII. By-Products of Cracking.

The list of by-products and "co-products" of cracking has continued to lengthen within the past year, and they are not only more varied but improved in quality.

Residuum from the cracking process may be treated to yield a marketable asphalt. One apparatus for this purpose[63] "removes usable gas oil from cracking still residuum" and leaves asphalt. The cracked residuum is treated in a fractionating tower at 720° F. under a pressure of about 50 mm. mercury. The lighter fractions, principally gas oil, are removed continuously as overhead vapours, and the asphalt remaining is a product of 150 penetration.

Taylor[64] describes a process of treatment of cracked fuel oil with steam and air at 450–550° F. to produce asphalt. The air-refining process is preferable, according to him, because of a higher yield, easier control, and the fact that the heat generated by oxidation is usually sufficient to maintain the reaction temperature. One commercial operation is reported to yield 75 per cent. asphalt in a continuous manner.

The production of asphalt from cracked residues, according to Hausman,[65] results from the controlled polymerisation of unsaturated heavy hydrocarbons formed in cracking. He says: "A series of complicated reactions takes place in the cracking apparatus under the influence of high temperatures and pressures.

[62] *Ind. Eng. Chem.*, 1932, **24**, 1277; *J. Inst. Petr. Techn.*, 1932, **18**, 475A.
[63] *Heat Eng.*, Dec., 1931, p. 189.
[64] *Trans. Inst. Chem. Eng.*, 1931, 3.
[65] *Nat. Petr. News*, 7.9.32, **24** (36), 26; *J. Inst. Petr. Techn.*, 1932, **18**, 468A.

During the course of this process, splitting takes place first, then polymerisation and condensation of the freshly formed products from the hydrocarbons. . . . The important point is that the cracking process should not be pushed too far." Semi-paraffin base oils, treated at 923° F. and 172 lb. per square inch, yielded 53 per cent. of a residue of specific gravity 1·005 at 59° F., Engler viscosity at 212° F. of 6·22°, and 1·5 per cent. soluble in benzole. This residue, steam distilled, yielded an asphalt which had higher specific gravity, ductility and penetration than an asphalt of the same melting point distilled directly from asphaltic crude. Similar production of asphalt from cracked residues, by vacuum distillation, steam distillation or air blowing at 300° C., is reported by Sakhanov and Loginova.[66]

Staley[67] describes several vacuum fractionating units which charge cracked fuel oil of 1·02 specific gravity, 2000–3000 seconds Furol viscosity at 122° F., flash point 400° F. and 1 per cent. B.S. The products are 30 per cent. cracking stock and 70 per cent. of an asphalt melting at 153° F. Another asphalt plant runs heavy Mexican crude oil, reduced Venezuela crude, or cracked residuum from Luling crude to yield naphtha, gas oil, fuel oil and asphalt of 40–50 penetration at 77° F.

In the same article Staley points out the value of petroleum coke as a fuel for refineries, citing its high calorific value (15,000 B.Th.U. per lb.) and low ash content (below 2 per cent.). He describes several coking processes, including the non-residuum cracking operation which yields gasoline, gas and coke as sole products from the charge.

An extensive series of tests was made in the laboratory by Morrell and Egloff,[68] who used a pressure still to produce gas, gasoline, Diesel oil and coke from a large number of oils from Albania, Argentina, Burma, Egypt, Canada, Mesopotamia, Peru, Persia, Rumania, Russia, Trinidad, Venezuela, California, Texas, Arkansas, Illinois, Kansas, Kentucky, Louisiana, Michigan, Wyoming, Oklahoma and Pennsylvania. The per cent. of coke produced by atmospheric distillation ranged from 1 to 25 per cent. After pressure cracking it ranged from 6·2 to 40·6 per cent. They point out that 15 years ago cracking still coke was unused, while in 1930 it comprised 83 per cent. of the total 1,934,000 tons in the United States.

The application of cracked residues as special fuels has been receiving attention in Russia. Bespolov[69] describes three tractor

[66] *Groznenskii Neftyanik*, 1931, **1** (6–7), 69; *Chem. Abs.*, 1932, **26**, 4943.
[67] *Petr. Eng.*, Feb., 1932, **3** (5), 20; *J. Inst. Petr. Techn.*, 1932, **18**, 174A.
[68] *J.S.C.I.*, 1932, **51**, 467; *J. Inst. Petr. Techn.*, 1932, **18**, 267A.
[69] "Repts. Conf. on Cracking Hydrog.," Grozny, 1931, **1**, 304; *Chem. Abs.*, 1932, **26**, 1105.

fuels produced from vapour phase cracked residues. One of these products was a heavy fuel containing 12 per cent. unsaturates, 22 per cent. aromatics, 38 per cent. naphthenes, and 28 per cent. paraffins. Another tractor fuel was light and contained 17, 18, 24 and 41 per cent. of the respective hydrocarbon groups. The third was a pressure distillate fuel containing 19, 15, 24 and 42 per cent. of the above groups, respectively. Shchitinov[70] deals with cracked residues from Grozny mixed-base fuel cracked in liquid-vapour phase. These residues, according to his tests, were mixed with lighter products to produce fuel oil of comparatively low viscosity and low pour point.

The use of cracked residuum as a source of lubricating oils is reported by Reisner,[71] who suggests that the recovery of lubricating oils by extraction of refinery residues with solvents might be applied to cracked residuum.

Synthetic lubricating oils, obtained by cracking crude paraffin wax and polymerising the olefins with aluminium chloride, have been closely examined by Barnard.[72] He finds them extremely resistant to oxidation in service, especially in airplane engines and for similar uses where the oil, in finely divided condition, is exposed to oxygen at high temperatures. Very low carbon formation rates have been shown by these studies; and the percentages of asphaltenes found were low when compared to analogous results on regularly manufactured lubricants.

Pressure still tar is brought under discussion by Beard,[73] who indicates a number of possible applications for what was once looked upon as a waste product. He claims that the pressure still tars, upon which he has experimented, resemble asphaltic base crude containing no gasoline or kerosine and may be refined to obtain "pressure still charging stock, lubricating oil, asphalt, pitch, and coke. The pressure still tar must be cracked at higher temperatures than virgin cracking stocks, to yield comparable products." It is reported that 50 per cent. overhead fraction of such a tar may be cracked to yield approximately 23 per cent. of a gasoline of the same octane number as that from the original stock. The 50 to 80 per cent. fraction of the tar was treated to yield lubricating oil representing 9–10 per cent. of the tar and having a viscosity of 167″ Saybolt at 130° F. Beard also describes the treatment of such pressure still tar to produce asphalt and binders, or coke and pitch.

A synthetic resin, different from the usual gum deposit

[70] *Groznenskii Neftyanik*, 1931, **1** (8–10), 89; *Chem. Abs.*, 1932, **26**, 1105.
[71] *Azer. Neft. Khoz.*, 1932, (4) 58; *Chem. Abs.* 1932, **26**, 4165.
[72] *Nat. Petr. News*, 1932, **24** (46), 62.
[73] *Oil & Gas J.*, 1932, **30** (46), 56.

encountered in petroleum refining, is being produced from cracked distillates, as reported by Thomas and Carmody.[74] Treatment of a distillate, containing hydrocarbons of varying degrees of unsaturation, with a metallic halide catalyst results in both condensation and polymerisation. Where a high yield of the resin is desired, conditions of cracking are changed to produce a distillate rich in diolefins and olefins. The reactions involved in treating this unsaturated distillate with aluminium chloride are thought to be of four types :—

"1. Reaction of olefins to form high-boiling oily polymers. 2. Reaction of olefins with aromatics to form substituted aromatics. 3. Polymerisation of diolefins and olefins to form resins. 4. Reaction of diolefins with substituted aromatics to form resins."

One of the interesting fields in which petroleum distillates are useful is the preparation of insecticides. Gothard[75] has investigated the characteristics of insecticides using various oils as bases and has found that cracked distillates are more toxic—particularly for houseflies—than straight-run fractions. The two disagreeable and unsuitable characteristics of the cracked product are odour and propensity toward gum formation. Treatment with sulphuric acid has removed some of the odour but decreased toxicity at the same time.

Alcohols as co-products of cracking continue to afford interest to experimenters. Gerr[76] separated ethylene from the other constituents in cracked gases and converted it to ethyl alcohol by solution in sulphuric acid to which 1 per cent. of silver or iron was added as catalyst. The silver catalyst gives a 13–15 per cent. yield while the iron gives only 8 per cent. Gas from cracking was treated by Holzman[77] to free it from sulphur, water, and gasoline. The 13–15 per cent. propylene and homologues present in the gas gave the maximum yield of alcohols with the use of 90 per cent. sulphuric acid, the products being isopropyl and a mixture of butyl and amyl alcohols.

A number of solvents which may be prepared from cracked petroleum products are given by Park,[78] including ethyl-, isopropyl-, amyl- and sec. hexyl-alcohols, ethyl and isopropyl ether, ethylene glycol ether, esters of these ethers, ethylene dichloride, amylene chloride and dichloramylene.

---

[74] *Ind. Eng. Chem.*, 1932, **24**, 1125 ; *J. Inst. Petr. Techn.*, 1932, **18**, 448A.
[75] *Manu. Chem.*, 1932, **3**, 170 ; *Soap*, 1932, **8** (6), 103 ; *J. Inst. Petr. Techn.*, 1932, **18**, 311A.
[76] *Azer. Neft. Khoz.*, 1932 (2), 15 ; *Chem. Abs.*, 1932, **26**, 2853.
[77] *Allgem. Öl u. Fett-Ztg.*, 1931, **28**, 245.
[78] *Mat. grasses*, 1931, **23**, 9375.

VIII. Cracking Equipment.

Important factors in the commercial application of cracking are construction, protection, and arrangement of plant equipment. A number of new and remodelled refineries illustrate the advantages to be gained by careful plant arrangement to give greatest efficiency from the available apparatus. Woods[79] describes a new refinery in Japan which comprises two units, one for topping and cracking, the other for making lubricating oil from heavy crude, or to rerun pressure distillate. In the first unit, light crude is topped into a straight-run gasoline, kerosine, and gas oil, and the residue is cracked at 750 lb. pressure and 850° F. The topping-cracking unit has a capacity of 3000 barrels per day of 28° A.P.I. gravity crude. The second unit fractionates a heavy crude into several grades of lubricating oil, or reruns the pressure distillate.

A cracking plant, described by Mack,[80] illustrates the trend toward larger units and multiple heating coils. The "multiple furnace" contains two cracking coils which discharge into a common secondary system, lending added flexibility to the plant. Flexibility is reported by Woods[81] as the keynote of one large cracking plant. The unit is said to be adaptable to various methods of processing different types of stocks. The operation is carried out in two stages—viscosity breaking, which comprises cracking residuum to fuel and gas oil, and then cracking the gas oil to pressure distillate. Each stage, being separate, can be operated under optimum conditions for its particular charging stock. In the viscosity breaker, conditions are 850° F. and 800 lb., while the other cracking conditions are 1200 lb. and 900° F.

What is said to be the largest combination skimming and cracking plant ever built, is reported by Conine[82] to be under construction. The unit is reported to be able to convert 20,000 barrels of crude oil daily into 70 per cent. gasoline of 70 octane number. The only by-products of the operation will be the refinery gas and a superior grade of fuel oil having a viscosity of about 150–200 sec. Furol at 122° F. The unit combines skimming off of light gasoline, "reforming" of heavy gasoline, a "viscosity-break" operation on the reduced crude followed by cracking under flashing conditions.

Beshentzev[83] criticises the layout of a new Grozneft plant and recommends the following procedure: "Gas oil is cracked in a pipestill and passed through a reduction valve into an evaporator.

---

[79] *World Petr.*, 1932, **3**, 290; *Refiner*, 1932, **11**, 542.
[80] *Refiner*, 1932, **11**, 502.
[81] *Petr. World*, 1932, **29**, 28.
[82] *Oil & Gas J.*, 1932, **30** (42), 22.
[83] *Groznenskii Neftyanik*, 1931, **1** (8–10), 72; *Chem. Abs.*, 1932, **26**, 1104.

The residue is withdrawn from the bottom while the vapours are passed into the bubble tower to separate the gasoline. The cracked residue from the evaporator is passed into a steam-vacuum evaporator, where an asphalt is obtained while the gas oil separated as vapour is condensed."

In a "completely modernised refinery" described by Miller[84] an old furnace was replaced by a new radiant type, provided with wall roof tubes in the radiant section in addition to the screen, soaking and preheating banks in the convection section. Direct steam hot-oil pumps were replaced by steam turbine-driven centrifugals. Additional heat exchanger and condenser capacity was installed.

Another cracking plant of similar type was modernised by additional equipment. Capacity was increased, according to Foster,[85] from 500 to 1200 barrels per day, maintaining percentage yields and high anti-knock quality gasoline. A pair of hot-oil pumps were added to the original installation as well as floor tubes in the furnace. An additional pipe-still as a preheater, along with a small preheater tower, aided in recovering sensible heat previously lost.

Foster[86] reports the modernisation of a liquid-vapour-phase cracking plant which now produces a relatively high yield of finished gasoline. The result was achieved by the addition of vapour-phase treating towers, two bubble towers, a flash chamber and flash dephlegmator, a vapour-recovery unit and auxiliary equipment.

A complete system for stabilising pressure distillate, recovering absorption gasoline from gas and vapours, and stabilising the absorption gasoline thus produced was installed in one refinery by Burrell and Mase.[87] They point out that all controls are automatic, so that the only attention required for operating the stabiliser is given by the regular cracking still operators.

Another stabilisation unit, intended to reduce gasoline losses to a minimum and raise the anti-knock value of the gasoline, is described by Conine.[88] The new installation includes an absorption tower, a fractionating column, a rectifying debutaniser, and a stabiliser, all inter-connected.

Kallam[89] discusses general developments along the lines of stabilisation and vapour recovery in modern plants. He points

[84] *World Petr.*, 1932, **3**, 73.
[85] *Nat. Petr. News*, 1932, **24** (6), 29.
[86] *Nat. Petr. News*, 3.2.32, **24** (5), 28; *J. Inst. Petr. Techn.*, 1932, **18**, 132A.
[87] *Nat. Petr. News*, 1932, **24** (4), 63.
[88] *Oil & Gas J.*, 3.12.31, **30** (28), 16; *J. Inst. Petr. Techn.*, 1932, **18**, 58A.
[89] *Refiner*, 1932, **11**, 231; *J. Inst. Petr. Techn.*, 1932, **18**, 178A.

out that stabilisation is now used to satisfy the increased rigidity of gasoline specifications, particularly as to vapour pressure.

Samsonov[90] contributes a discussion of the various chances for water to enter a cracking unit and preventive methods therefor.

Temperature and pressure control in cracking plants receives its share of attention. Poole and Younkin[91] describe up-to-date automatic temperature control for tube still operation. Another temperature control by De Florez[92] consists essentially of a potentiometer with an attachment so that the fuel control contacts are made through the cam mechanism, resulting in an electrical contact directly proportional in duration to the deflection of the galvanometer. This deflection is in turn directly proportional to the temperature either above or below the point selected.

Vandenberg[93] finds that automatic remote control instruments govern the operation of cracking stills more efficiently, reliably and safely than manual control. He states that, to get the most out of a control system, it should indicate all pressures, temperatures and quantities. The cracking coil requires the closest attention, because it operates at the highest temperature and pressure. He advocates the flow controller which gives good results when attached to the discharge of a centrifugal pump.

Developments in the design of all kinds of cracking plant equipment have been commented upon and discussed. Staley[94] emphasises co-operation in such design between fabricators of cracking equipment, refinery engineers and metallurgists. "Practically any part for a cracking unit is now available in alloy steel," he says. Foster[95] summarises briefly some of the year's developments in design and construction of "liquid-phase cracking plants." An earlier article[96] illustrated application of these trends in design resulting in production of 70 per cent. or more of a 74 octane number gasoline from Pennsylvania gas oil and heavy naphtha. Theoretical considerations in the design of high-pressure equipment involving paraffin hydrocarbons are the theme of a series of discussions by Brown and co-workers[97] who derive empirical equations to be applied to engineering design.

The methods of fabrication of high-pressure vessels and their relative merits are treated by Egloff, Morrell and Leonhardy.[98]

[90] *Groznenskii Neftyanik*, 1931, **1** (4–5), 80; *Chem. Abs.*, 1932, **26**, 2308.
[91] *Petr. Eng.*, 1932, **3** (3), 35.
[92] *Petr. Eng.*, 1932, **3** (12), 37.
[93] *Refiner*, 1932, **11**, 396; *J. Inst. Petr. Techn.*, 1932, **18**, 396A.
[94] *Petr. Eng.*, 1932, **3** (12), 31.
[95] *Nat. Petr. News*, 1932, **24** (30), 29.
[96] *Nat. Petr. News*, 1932, **24** (9), 25.
[97] *Ind. Eng. Chem.*, 1932, **24**, 513 et seq.; *J. Inst. Petr. Techn.*, 1932, **18**, 270A.
[98] *Ind. Eng. Chem.*, 1932, **24**, 1264; *J. Inst. Petr. Techn.*, 1933, **19**, 26A.

They describe riveted, hammer-welded, electric-welded and pierce-ingot types of reaction vessels, and discuss not only their methods of manufacture but also the materials used, their strength under various temperature-pressure conditions, wall thickness, life thereof, and the X-ray method of weld-testing. Raymond[99] also discusses pressure vessels of the shield-welded type. He claims joints of nearly 100 per cent. efficiency between parts of almost any thickness or shape, so that the welding of plates into pressure vessels results in performance comparable to that of single pierced ingot vessels.

A method for the calculation of dimensions of liquid-vapour-phase cracking equipment is advanced by Riabih,[100] based on the assumption that "we can calculate the speed of cracking under any given temperature if we know the speed of the process under some one temperature." The relation developed is $C=C_o 2^{\left(\frac{T-T_o}{T_o}\right)}$ where C_o is the speed of reaction at temperature T_o and C at T. These calculations have been adversely criticised by Khohlov and Markosov,[101] who claim that Riabih erred in three assumptions, basing their calculations on plant data. The three errors were: (1) figures used for the heat of cracking reaction; (2) failure to consider vaporisation of naphtha; (3) temperature fall in reaction chamber is proportional to naphtha formed and not to time of product in reaction chamber.

The accuracy of various methods of measurement of high temperatures and pressures is considered by Keyes[102] in an article on high-pressure technique. He finds that a precision of measurement of 1 part in 10,000 up to 600 atmospheres pressure is not difficult with the piston gauge. The most dependable secondary standard temperature-measuring device is thought to be the platinum resistance thermometer. He advocates measuring volumes under pressure by designing the container in such a way that the classical elasticity theory may be employed to compute volume changes due to pressure.

Monrad[103] interests himself in the calculation of heat transmission in convection sections of pipe stills. He derived simple equations for calculating the heat transfer coefficients from gases to staggered tubes of cold surfaces by convection or radiation, and found that application of theory to practice gave good agreement.

---

[99] *Refiner*, 1931, **10** (12), 90.
[100] *Nat. Petr. News*, 1931, **23** (48), 43.
[101] *Nat. Petr. News*, 1931, **23** (5), 29.
[102] *Ind. Eng. Chem.*, 1931, **23**, 1375; *J. Inst. Petr. Techn.*, 1932, **18**, 101A.
[103] *Ind. Eng. Chem.*, 1932, **24**, 505; *J. Inst. Petr. Techn.*, 1933, **18**, 271A.

Kiley and Mangsen[104] also experimented with heat transmission to oil flowing in pipes, and reported results of interest for cracking equipment from the point of view of heat inputs and temperature measurements.

Brown and Souders[105] offer design data for vapour recovery and recitfying units which they claim accurate for engineering computations at pressures up to 500 lb. They find that Raoult's law, applied in such cases, would introduce an unnecessarily large error which their method eliminates.

The furnace has been characterised as the "heart of the cracking installation." and upon it depends much of the success of operation. Uniformity of temperature is considered particularly important by Sosman,[106] who finds the best conditions in furnaces in which the gases are in turbulent flow. A new type of electric resistance furnace is described in which the air is circulated by a fan. He finds that the high-frequency induction method of heating is a new tool capable of producing almost perfect uniformity in a liquid conductor. Nash[107] also discusses the problem of refinery furnace design, tracing its development from the original type to the present.

An "improved furnace" for a cracking still is offered by Westsmith.[108] The furnace is constructed with a heater in which incoming air is passed back and forth before entering the combustion chamber and combustion gases are passed through the radiant zone to the back wall where a down draft pulls them past the air heater to the convection zone. The radiant tubes are protected from direct impingement of the flames, and it is possible to use long tubes in the radiant zone because of the ability to keep the span between two successive supporting points well within the limits of safety.

Pfau and Barrere[109] describe the installation of floor tubes in a cracking furnace in order to produce more gasoline without increasing the crude throughput. The ducts for air admittance were replaced in the furance so as to serve as supports for the new floor tubes. No coking trouble was experienced in the floor tubes when operation was resumed.

One of the most important factors in cracking furnace operation, according to Reintjes[110] is the construction of the walls. The author

[104] *Trans. Am. Inst. Chem. Eng.*, 1931, **27**, 154.
[105] *Oil & Gas J.*, 1932, **31** (5), 34.
[106] *Ind. Eng. Chem.*, 1931, **23**, 1369.
[107] *Petr. Eng.*, June, 1932, **3** (9), 76; *J. Inst. Petr. Techn.*, 1932, **18**, 940.
[108] *Nat Pret. News*, 6.4.32, **24** (14), 31; *J. Inst. Petr. Techn.*, 1932, **18**, 223A.
[109] *Petr. Eng.*, Nov., 1931, **3** (2), 32; *J. Inst. Petr. Techn.*, 1932, **18**, 179.
[110] *Petr. Eng.*, June, 1932, **3** (10), 72; *J. Inst. Petr. Techn.*, 1932, **18**, 354A.

emphasises the need for flexibility in furnace walls to avoid distortion. He advises the use of more joints in order to localise expansion and prevent the accumulated expansion which tends to move the wall endwise.

A further discussion of cracking furnaces is offered by Khokhryakov and Zherdev[111] who show the heat balance of a furnace and discuss faults of construction.

Corrosion continues to be a serious problem in high pressure, high temperature equipment. Two devices for determining the degree of wear in cracking still tubes have recently been reported. One was described by McMonagle[112] as a gauge for measuring tube diameter and consists of "spring-actuated rollers which are kept in contact with the interior walls of a tube and which are connected to an indicating dial on the opposite end of the device." Another instrument for studying inside tube walls is a telescope devised by Zeiss.[113] It consists of a tube having several extensions, reflecting heads, and telescopic lenses, supports to hold the telescope in the centre of the tube, and electric lighting to illuminate within the field of the telescope.

Morrell and Egloff[114] discuss the corrosion of cracking equipment, holding it as a function of the type of sulphur compound rather than sulphur content of the oil. They review various methods of counteracting corrosion in cracking equipment and cite as satisfactory the use of ganister and non-metallic linings. They find alloy steels suitable but costly. Elliott[115] presents an extensive discussion of the general field of corrosion-prevention, and favours alloys for special cases. He points out, "In an important oil field, nickel-chromium alloy steels of varying compositions, as well as cast iron, fire clay, and silica ware have definitely failed for gas pyrolysis at cracking temperatures of between 850° and 900° C. chromium iron, containing 28 per cent. chromium, three months service was obtained, but failure ultimately occurred by embrittlement although there was no evidence of carbonisation." He indicates that, in cracking equipment, screw plugs of 8 : 20 chrom-nickel steel gave 25,000 hrs. service; tubes of 4–6 per cent. chromium alloy have three times the life of carbon steel tubes; and tube supports serve 2½ years when fashioned of 15 : 35 chrome-nickel alloy.

---

[111] "Repts. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 257; *Chem. Abs.*, 1932, **26**, 1105.

[112] A.P.I. Meeting, Houston, Texas, Nov., 1932; *Nat. Petr. News*, 1932, **24** (46), 49.

[113] *Nat. Petr. News*, 1932, **24** (46), 24.

[114] *Ind. Eng. Chem.*, 1932, **24**, 509; *J. Inst. Petr. Techn.*, 1932, **18**, 271A.

[115] *J.S.C.I.*, 1932, **51**, 502, 527.

The use of refractory materials for corrosion resistance is the subject of an article by Ryschkewitzch.[116] He indicates that refractories based on clay are not satisfactory much above 1600° C. The author discusses a number of commerical refractories including zirconium silicate suitable up to 1750° C., alumina up to 1800° C., spinel MgO. Al_2O_3, beryllium oxide, zirconium oxide suitable at temperatures of 1700° C., magnesium oxide, and thorium oxide. As an outgrowth of Ryschkewitzch's investigation, a high temperature furnace was developed to make use of some of the refractories.

A study of corrosion by hot vapours of cracked gasoline, conducted by Bespolov,[117] was reported for the following metals with decreasing corrosion in the order: lead, copper, Babbitt metal, cast iron, brass, tin, iron, and steel.

Armsby[118] includes, in his discussion of lime in the petroleum refinery, the application of that substance to the prevention of corrosion in cracking stills. He claims that the addition of a lime-oil slurry to the charging stock as it enters the still will frequently greatly reduce, or completely stop, corrosion in the tubes. A table of lime dispersion in the cracking unit with such lime-treated stock is given.

IX. Reviews on Cracking.

The field of cracking, its achievements and development, has been reviewed from several points of view. Hirsch[119] considers the problems of modern cracking technology with emphasis upon the flexibility in design and operation. The importance of cracking to the petroleum industry is the angle from which Frederichs[120] surveys the development of cracking for the production of liquid fuels.

A review of modern cracking is offered by Pöll[121] who treats it from both theoretical and practical points of view. He divided cracking systems into six groups, including cracking at atmosphere pressure at low temperatures, pressure cracking in liquid phase, pressure cracking simultaneously in liquid and vapour phase, pressure cracking in vapour phase, cracking with catalysts, and cracking with simultaneous hydrogenation of the products.

Dobrescu[122] presents a historical and statistical review of the cracking operation from its introduction into the petroleum

[116] *Chem. Met. Eng.*, 1932, **39** (2), 85.
[117] "Rep. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 358; *Brit. Chem. Abs.–B.*, 1932, 455.
[118] *Refiner*, 1932, **11**, 415; *J. Inst. Petr. Techn.*, 1932, **18**, 393A.
[119] *World Petr.*, 1932, **3**.
[120] *Allgem. Öl- und Fett-Ztg.*, 10.11.31, **28**, Mineralöl No. IV., 42.
[121] *Oesterr. Chem. Ztg.*, 1932, **35**, 115.
[122] *Mon. Petr. Roum.*, 1932 (8), 301.

industry to the present. Sakhanov[123] and Sakhanov and Tilicheev[124] offer reviews of the progress in cracking, discussing the "foundations" of cracking, recracking, non-residuum cracking, and mild cracking.

There are also a number of reviews of the refining industry as a whole, which include discussions of cracking as an important part. Staley,[125] in discussing the refining operations in Texas, describes the cracking units in operation in the state and their daily capacities.

Cracked gasoline has been given its place in the limelight by Camp[126] who emphasises its fine anti-knock quality; while Schmitz[127] in a similar review of refining gives cracking a prominent position.

In a technical survey, Waterman and Tulleners[128] deal with the chemistry of petroleum, including the chemistry of cracking. Naphtali[129] offers a study of the theory and development of the cracking process as a means for obtaining motor fuel. He includes descriptions of various commercial operations.

---

[123] "Repts. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 5; *Chem. Abs.*, 1932, **26**, 1102.
[124] "Repts. Conf. Cracking Hydrog.," Grozny, 1931, **1**, 20; *Chem. Abs.*, 1932, **26**, 1103.
[125] *Petr. Eng.*, 1932, **3** (13), 107.
[126] *Nat. Petr. News*, 1932, **24** (7), 29.
[127] *Petr. Z.*, 1932, **28** (26), 1.
[128] *J. Inst. Petr. Techn.*, 1932, **18**, 429.
[129] "Chemische Technologie der Neuzeit," vol. V.

Distillation and Fractionation Equipment.

By Dr. R. K. Fischer.

Refining.

During the year 1932 the developments which have taken place in oil refining have closely reflected the economic conditions prevailing throughout the world, and it may be considered a natural consequence of the economic crisis that advances have been largely confined to development of theory and the improvement of previously established processes. Relatively few new plants have been erected and such as have been built mainly conform with well established types, although a few represent the application on a commercial scale of new processes.

A more thorough application of thermodynamical principles to problems of heat transmission and energy conversion has resulted in a closer approach towards maximum efficiency. Processes for chemical treatment and extraction have been proposed which combine higher efficiency and selectivity than previously. Heat recovery in all distillation processes is one of the most important features in refinery engineering. Progress in the production of stable and high quality products can be traced throughout the past year. Furthermore, we can state that the stress under which the oil industry has had to operate during the past year was responsible for many improvements and refinements. During the year it was not the imposing size and number of new refineries which testified to progress in the industry, but rather the work done in laboratories and other research centres. Where new refinery equipment has been constructed the tendency has been to install larger capacity units in order to secure higher operating efficiency.

Probably the largest crude oil distilling units now running for the production of high-grade lubricating stocks are two 14,000 barrel per day two-stage units which have recently been constructed in a large refinery situated in one of the Southern States of the United States.[1] These units are of the now more or less generally accepted design, both the atmospheric and vacuum stages being complete with their own still, tower, heat exchangers and pumping equipment. In addition to the normal vacuum stage a flash jug representing a secondary vacuum stage has been installed for handling the heavy products. As a high-grade cylinder stock must be taken as a distillate, it is necessary to keep temperatures as low as possible, thus requiring the highest possible vacuum. In the flash zone of the primary vacuum stage the

[1] J. C. Glenn, *Petr. Eng.*, 1932, **3** (4), 58–60.

absolute pressure is higher than that at the top of the tower owing to the pressure drop through the fractionating plates in the tower. This increased pressure in the flash zone would result in high temperatures and/or a large steam consumption when taking high-grade cylinder stock as a distillate. To overcome this the cylinder stock is taken from the primary vacuum tower in the residue, which is then introduced into a secondary vacuum flash-chamber, the so-called vacuum flash jug, in which the absolute pressure is considerably lower than in the primary flash zone and practically the same as at the top of the main vacuum tower. Under these conditions the cylinder stock can be taken off at a lower temperature.

Another large unit now in operation in an Atlantic Seaboard Refinery is of interest.[1] The construction of this unit was completed towards the end of 1931, and the unit is capable of re-running 8000 barrels per day of pressed wax distillate, or the same quantity of bright stock solution, or a blend of these two stocks.

Recently cracking heaters, of capacities greater than has hitherto been thought practicable, have been erected in America.

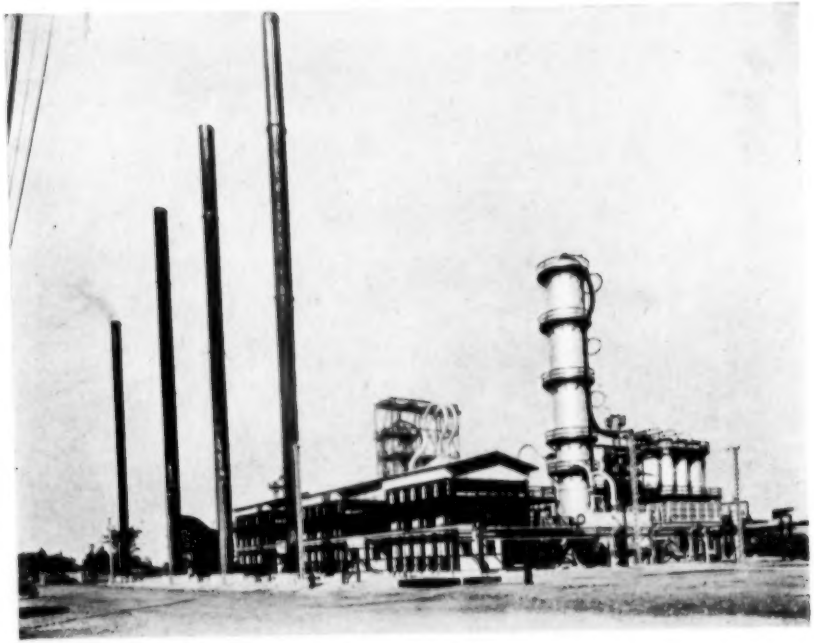
The new specifications for motor fuel which have been announced in the United States will undoubtedly cause considerable changes in distilling practice, and in the methods of production of the products involved. As far as is known a considerable number of States are prepared to adopt these specifications immediately.

The vapour-pressure specification of the fuel is the one mostly affected, this being given as a maximum Reid pressure of 12 lb. per sq. in., or in tropical regions, 8 lb. per sq. in.

The new requirements may not influence to any great extent the production of straight-run gasoline, but considerable changes will be necessary in the manufacture of recovered gasoline and cracked gasoline. As in modern refinery practice these two products constitute the major portion of light fuels, many refineries will be forced to adopt some method of lowering the vapour pressure of their gasoline. The vapour pressure of finished gasoline can, of course, be regulated by changing the pressure-temperature conditions during distillation and condensation, but it has been proved that in many cases it is more economical to instal new equipment rather than adapt existing plant to permit of the production of lower vapour-pressure products.

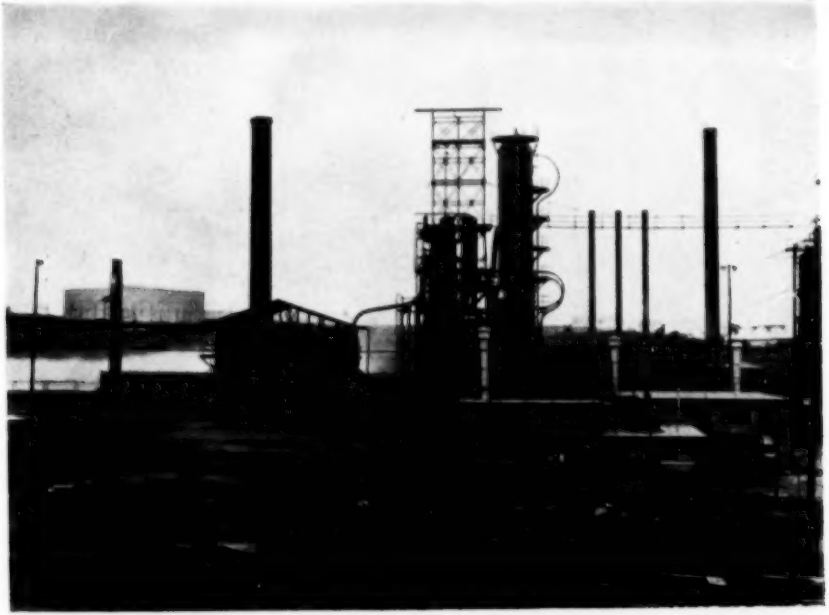
In every case the problem is to free the gasoline of its most volatile constituents, *i.e.*, low boiling point hydrocarbons, hydrogen sulphide and other gases. In the case of straight-run gasoline this can be accomplished either by treatment of the gasoline itself, or more economically by stabilisation of the crude oil.

FOUR TWO-STAGE ATMOSPHERIC-VACUUM DISTILLING UNITS FOR CRUDE OIL.—*Courtesy of Foster Wheeler, Ltd.*

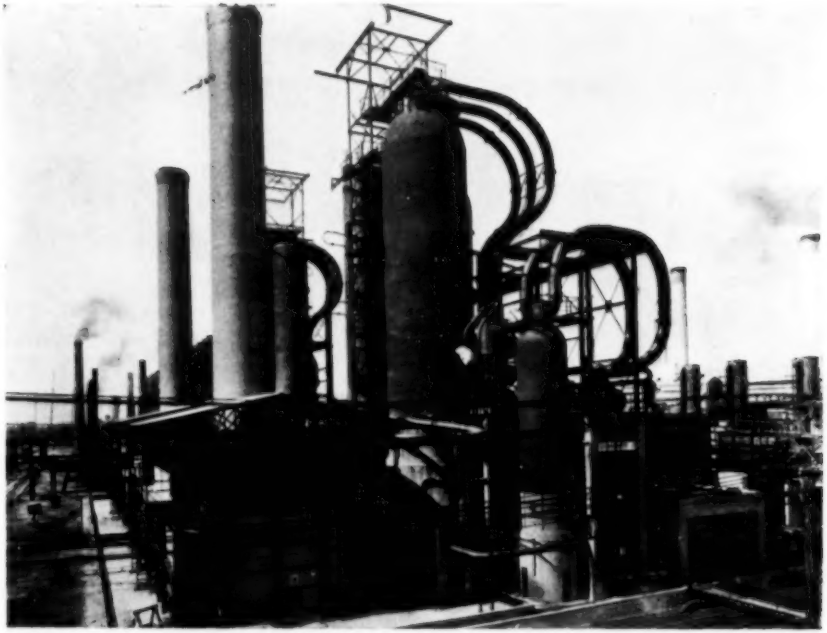


COMBINED SKIMMING AND CRACKING, REFORMING AND RE-RUNNING UNIT.
—Courtesy of A. F. Craig & Co., Ltd.

COMBINED SKIMMING AND CRACKING, REFORMING AND RE-RUNNING UNIT.
—Courtesy of A. F. Craig & Co., Ltd.



DUBBS CRACKING UNIT WITH FOSTER WHEELER TUBE STILL.
—Courtesy of Dr. V. Henny, representing Universal Oil Products Co., London.



VACUUM FLASH JUG OPERATING IN CONJUNCTION WITH A TWO-STAGE ATMOSPHERIC-VACUUM DISTILLING UNIT. FLASH JUG ON RIGHT OF UNIT.

—Courtesy of Foster Wheeler, Ltd.

One seaboard refinery in France has installed a complete crude oil stabilising unit in which the crude oil is stripped of the light portions mentioned above, and, in addition, there is provision for preliminary treatment for the removal of sediments, soluble salts and acids.[2]

The light gasoline which is secured as a distillate during the stabilisation of the crude oil is recovered and stabilised in a gasoline stabilising unit connected to the crude oil unit, and is subsequently used for blending purposes. It is estimated that this high-grade blending gasoline will pay for most of the costs of pre-stabilising the crude oil. In addition there will be the benefit of handling clean and non-corrosive crude oil in the refinery, with resultant savings in cost due to the diminution of corrosion and deposition.

Up to the present heating in distilling units has been done more or less exclusively either by direct firing or by steam heating. It now seems as if indirect heating mediums other than steam are becoming more and more popular. This is due to the desire to use high transmission temperatures without the use of a heating medium at high pressure, and also to maintain closer control over the heat transmission process.

The Indian Refining Company have developed the Govers system using diphenyl vapours.[3] The diphenyl is heated in a special furnace, and heat is transmitted to the oil by circulation of the diphenyl. It has been shown that there is practically no decomposition of the diphenyl, but the high temperatures involved in this process combined with the characteristics of the heating medium necessitate the use of special high resistant pipe material. Another feature of this process is that the risk of local over-heating of the oil is practically eliminated, thus permitting operation at a high mean temperature level.

Mercury vapours have been used instead of diphenyl,[4] this process being used by the Sun Oil Company, the heating of the mercury being carried out in equipment similar to that used in the case of diphenyl. It is claimed that the results obtained are superior to those secured with the conventional type of heaters.

Several film type evaporating processes have been developed in an attempt to secure distillation at the lowest possible temperature. Of these the d'Yarmett process[5] developed by the International Petroleum Processes Inc. appears to be the most important. The heating is carried out in vertical cylindrical vessels located in a furnace, a rotator being installed in each vessel to throw the

VACUUM FLASH JUG OPERATING IN CONJUNCTION WITH A TWO-STAGE ATMOSPHERIC-VACUUM DISTILLING UNIT. FLASH JUG ON RIGHT OF UNIT.
—*Courtesy of Foster Wheeler, Ltd.*

[2] A. S. Wolfner, *Refiner*, 1933, **12**, 8–10.
[3] *Refiner*, 1932, **11**, 74.
[4] *Refiner*, 1932, **11**, 78.
[5] *Refiner*, 1932, **11**, 62.

oil against the wall and thus create a continuous film. The vaporised portion of the oil is removed from the space around the rotator and conducted to a conventional bubble tower. This method appears to be absolutely in accordance with the conditions required for evaporation, but it remains to be proved whether the inherent mechanical and coking difficulties of such a process can be overcome in a commercial sized plant.

Throughout the oil industry the use of pulverised coke as fuel, either for direct heating systems or for the more recently developed indirect heating processes, is increasing.[6] Although the knowledge of the high fuel value of petroleum coke is not new, it has not been extensively used in refineries owing to the lack of suitable burners. More recently very considerable development has taken place in the design of equipment for pulverising and feeding coke. Nevertheless in many cases it has been considered more economical to run crude oils for the production of asphalt rather than to run down to coke.

Higher overall efficiencies have been secured in refineries not only by increase of thermal efficiency, as described above, but also by increasing the percentage recovery of products from the crude oil as a result of the extensive use of gas recovery systems. General experience in distillation has shown that losses average about one per cent. of the charge between the crude oil distilling equipment and the storage of the finished products. It has also been recognised that these losses are caused principally by the evaporation of the light hydrocarbons, propane and isobutane.

As stated earlier in the paper, these two hydrocarbons if retained in the finished gasoline are largely responsible for its high vapour pressure. It was, therefore, a natural solution of the problem to eliminate propane and isobutane, which not only decreased the evaporation loss, but also permitted the butane content of the gasoline to be increased without raising its vapour pressure. Propane and isobutane are now being produced from gasoline recovery plants to an increasing extent in the form of "liquid gas." The hydrocarbons lighter than propane and butane are vented or rejected in the absorption and rectifying operation, and may be used if desired as fuel.

Modern crude oil stabilising plants produce a practical debutanization of the crude oil resulting in a higher quality gasoline, and a lower throughput in the primary distillation, and subsequent processes for the same output of products or, alternatively, an increased output from existing equipment. The size of new equipment for any specified output of products would be reduced if it were handling a pre-stabilised crude.

[6] F. R. Staley, *Petr. Eng.*, 1932, **3** (5), 20 (I. P. T., A.480).

Hydrogen sulphide, if present in the crude, will be removed during the pre-stabilisation process, thus resulting in a decrease of treating costs and replacements necessitated by corrosion. In many cases it is not possible to reduce the equipment comprising a vapour recovery system, which normally includes compression or absorption equipment, a still for stripping the rich oil, and equipment for stabilising recovered products, but under certain conditions it has been found possible to eliminate the absorption equipment and the stills.

The "Compression-Direct-Fractionation" method is one of the latest developments in vapour recovery.[7] In this process gases from the refinery, tank farm or fields, are compressed in the usual way, and discharged directly to the stabiliser which is of normal design. The gasoline is stabilised to the specifications required, and the non-condensable gases are vented from the reflux condenser. This method is considerably simpler than that usually employed, and will no doubt be adopted increasingly wherever the gas supply and analysis will permit.

Cracking both in liquid-phase and in vapour-phase has been further developed, and together with these processes the accessory methods of treating, etc.

The demand for products having high anti-knock properties has greatly influenced the development of cracking equipment. The effect of heating time and rate of heat input has been closely studied, and it is only quite recently that the importance of a steady temperature rise has been fully appreciated. This led to the development of special methods for the design of stills required for cracking plants, instead of using the design methods for ordinary distillation stills which had previously been used. The tendency in the design of cracking stills is to eliminate the "soaking" period of the oil in the still, particularly when handling heavy charging stocks.

An important feature of modern cracking is the re-formation of light naphthas to produce high anti-knock gasolines,[8] and a further trend is a combination of reforming and cracking which is accomplished by cracking the bulk of the stock in liquid-phase followed by secondary cracking in vapour-phase of the light material produced.

For this combined process pipe stills are used in which two or more separate streams are heated, and depending on the temperature range required the different operations are performed either in the convection or in the radiant heating zones of the

[7] P. M. Raigorodsky and N. K. Rector, *Oil & Gas J.*, 21.7.32, **31** (9), 11–14. *Nat. Petr. News*, 1932, **24**, 29–30.

pipe still. Where large capacities are involved separate pipe stills have occasionally been used.

It can generally be assumed that for reforming more severe conditions of temperature and pressure are required than for liquid-phase cracking, and depending upon the process this difference amounts up to about 300 lb. per sq. in. pressure and 200° F.[8] Up to the present time, however, these combined processes have not been proved to be definitely superior to those previously in use.

The handling of different stocks under different pressure and temperature conditions in the same furnace makes it necessary to secure more complete control over the flue gases than is normally necessary. This led to the installation of special dampers, deflection walls, special flues and air doors, the development of which required considerable work, particularly in view of the relatively high temperatures to be encountered.

Universal Oil Products Company, together with Foster Wheeler Corporation, have done considerable work along these lines, and the Winkler-Koch Engineering Company have also constructed a furnace of this type in the Mid-Continent area. M. W. Kellogg Company have developed a furnace which is representative of the combined type.

A further step in the reduction of costs is the combination of skimming and cracking plants in a single self-contained unit,[9] one advantage of this design being a very complete system of heat recovery with consequent lowering of fuel consumption, and in addition the capital cost appears to be relatively low.

Although the fractionation of pressure distillates has been continuously improved, the boiling range of these materials is still greater than that of straight run gasoline, and on account of this chemical treatment is more difficult and more involved if the evaporation and weathering losses are to be kept low. Nevertheless, the total distillate is usually refined as received from the cracking plant and redistilled later, although the latest practice is to debutanise the pressure distillate before treatment, thus reducing the capacity of both the treating and rerun plants.

The latest practice for rerunning pressure distillate is to use a two-stage unit,[10] the first stage operating at atmospheric pressure, open steam being used in the fractionating tower; the second stage operating under vacuum, with or without open steam in the fractionating tower depending upon the specifications imposed on the products.

---

[8] A. L. Foster, *Nat. Petr. News*, 1932, **24**, 27.
[9] C. J. Pratt, *Refiner*, 1932, **11**, 244–250.
[10] *Refiner*, 1932, **11**, 94.

In the early days of development of cracking equipment the colour of the cracked spirit was considered to be of considerable importance, and in order to secure a good colour distillate a large number of trays were installed in the fractionating towers of rerun units, and were responsible to some extent for the high cost of these plants.

Gradually it has been shown that the elimination of corrosive sulphur and undesirable gum-forming constituents is of greater importance than colour, and this has resulted in the cheapening of the fractionating and treating equipment in which the pressure distillate is processed.

In the manufacture of lubricating oils there are three main classes of oils to be considered: first, the distillates which are produced from the crude oil stock directly in the distilling unit, and constituting finished marketable products requiring no, or only slight, chemical treatment. The fractionation of these products must be highly effective, and special care must be taken to prevent cracking during the distillation process. For this duty distilling units, in which high vacuum in all parts of the unit is the most important feature, have been employed.

Secondly, wax distillates. Those which are afterwards pressed for the separation of wax must be well fractionated when the extraction of amorphous wax from the cylinder stock is carried out with the use of naphtha as a solvent. Under these conditions it is of extreme importance that no crystalline wax be present in the centrifugable cut.

With the use of certain solvents such as trichlorethylene used in the Nobel Dewaxing Process, it is claimed that the presence of crystalline wax in the centrifugable cut does not affect the separation. The use of such a process would therefore permit the use of less efficient and, consequently, cheaper fractionating equipment for the separation of the various wax cuts in the crude oil.

The third type of lubricating oils are reduced crudes which are subsequently subjected to redistillation in order to obtain the required viscosity. Good fractionation, although necessary, is not of extreme importance in this case, and the chief requirement is avoidance of cracking.

With the increased pressures used in certain refinery operations, the problem of selecting and testing material becomes of more importance. In June, 1931, the American Society of Mechanical Engineers published a revision of the Boiler Code, a remarkable feature of which was the inclusion of non-destructive tests for high pressure vessels. This is of greater importance than would appear at first glance in that it represents an entirely new feature

in commercial material testing. Up to the present tests have been carried out on samples of the material, test seams, etc., practically no non-destructive tests being carried out on the finished equipment.

The new regulation is of particular importance in its application to the testing of welded equipment, more especially as welded construction is becoming more and more popular for distillation equipment. One of the first plants constructed and tested under the new specification was the modern cracking plant of the Tide-water Oil Company at Bayonne, New Jersey, the large tanks for this unit having not only been tested exactly in accordance with the specifications of the Boiler Code but also subjected to additional tests. The welding of the bubble tower was examined with X-ray equipment furnished by the St. John X-Ray Service Company, and in addition to this test electro magnetic tests were made with the Sperry Electro Magnetic testing machine.

As the electro magnetic test is claimed to be less expensive than the X-ray examination, it is probable that the former will be brought into general use for the testing of high pressure vessels. In this test a current is passed through the weld, any defect in which affects the form of the magnetic field, and thus permits of the detection of faults. The changes in the magnetic field influence a balanced magnetic coil and are recorded by means of a relay and suitable instrument.

The importance of corrosion problems increases with the increase in temperatures employed in distillation equipment. Whereas for normal straight distillation operation a temperature of about 700° F. has represented the maximum to which the oil has been heated, modern cracking processes require considerably higher oil temperatures, and in consequence higher tube wall temperatures. This necessitates the use of more resistant steel, particularly in those sections of tube stills exposed to direct heat radiation.

V. V. Kendall and F. N. Speller[11] have reported on the recent developments in corrosion prevention of ferrous metals. The fundamental principles of corrosion have been thoroughly investigated, and it is now more or less generally understood that surface films and potentials are the governing factors in corrosion resistance.

Evans[12] has carried out interesting work which shows the influence of changes of potential on film formation. His previous work and study on the separation of these invisible films from metallic surfaces is well known, and has been of considerable

[11] F. N. Speller, *A.P.I. Proc.*, Dec., 1932, Section III, 102–113.
[12] U. R. Evans, *Chem. Trade J.*, 1931, **89**, 270 and *J. Inst. Metals*, 1931, **46** (2), 7–24.

importance to many manufacturers in connection with the production of corrosion resistant material.

The progress during the last few years in the study of films is of practical, as well as theoretical, value, investigations having shown that depending upon the character of the film, corrosion can be either inhibited or accelerated. Furthermore, the continuity of the film on the exposed surface has been shown to be of considerable importance. It is now recognised that discontinuous films are the principal cause of pitting.

The importance of this discovery lies in the fact that for the production of corrosion resisting equipment it is apparently of more importance to create a suitable surface—*i.e.*, a continuous resistant film than to find a material, the analysis of which would in itself render it resistant to corrosion, in view of the fact that this latter solution appears to be more expensive.

The artificial production of a dense and closely adherent film which will at the same time be self repairing, is now considered by many specialists to be a solution of most corrosion problems. Sodium silicate and sodium dichromate are examples of the practical application of the film theory. So far, however, the use of these films appears to have been applied in the refrigerating industry only. Both chromium and aluminium form stable surface films when exposed to sulphurated salt water, and are, therefore, of importance in the construction of condensing and cooling equipment for which no fresh water is available. Steel chromium alloys have proved to be more durable than carbon steel in the presence of corrosive sulphur compounds in pressure distillate. This would appear to recommend the use of such material, particularly in the re-forming units mentioned earlier in this paper.

Regarding heat resistance of ferrous metals, the results collected during the past year or so appear to indicate that exposure to hydrogen sulphide and oxygen at service temperatures is a reliable test for determining whether a metal is suitable for a special duty. The reproduction of full scale conditions in the laboratory is very desirable, in view of the saving effected when reliable tests of this type can be performed.

It has been shown that heat resistance can be increased by the use of chromium steel, but that the resistance does not increase proportionately with the chromium content above a certain figure, no appreciable additional improvement being observed when more than 4 per cent. chromium is present.

In pipe stills operating under severe conditions nickel has been used to stabilise the crystalline structure of the steel at high temperatures, but recent experience has shown that in several cases this has definitely reduced the resistance of the tube to heat

corrosion, although a satisfactory explanation of this phenomenon does not appear to have been discovered.

There have been many valuable publications on the use of silicon, aluminium and tungsten in steel for cracking still tubes, but no all-round alloy steel has been produced so far which could be universally adopted for all cracking units. As metal temperatures in modern distilling operations may reach 1400° F., the changes in metal structure become of considerable importance, and designers have had to make use of inhibitors which retard these changes. Nickel has been proved an efficient stabiliser for austenite, and the percentage used does not in general exceed about 8 per cent.

Segregation of chromium carbide in the grain boundaries has been observed in tubes under severe temperature conditions. This is most undesirable, as it impoverishes the surrounding areas of chromium. However, tungsten has been shown to counteract this.

In conclusion, while a survey of the progress of refining during the past year shows no revolutionary developments, a general all-round increase in the efficiency of existing processes is to be recorded. That such improvements are not of a spectacular character is no reflection upon their importance, nor is the nature of the progress wholly unexpected in view of the stringent economic conditions now existing whereby a process must be efficient in order to survive the economic stress to which it is subjected.

Chemical and Physical Refining.

By B. C. Allibone, A.R.C.Sc., B.Sc., A.I.C.

By reason of long acquaintance and supremacy even to-day sulphuric acid may be regarded as the principal chemical refining agent. It has in the past, for want of better methods, been applied to problems such as the drastic refining of semi-aromatic distillates for which purposes it was far from an ideal reagent. Its application is tending to be restricted to those cases in which limited proportions of acid suffice to produce the required effect. It continues to receive the closest attention with regard to its refining action and the elimination of the disadvantages attaching to its use. As the acid treatment of cracked distillates contributes a full quota of difficulties, particularly by the production of oil soluble and acid forming compounds, this application has been the subject of extensive investigation.

Using distillate secured from a mixture of Smackover Crude and Winkler County Crude Residue by cracking at 300 lb. pressure and 900° F., Trusty[1] has investigated the following refining variables—time of agitation, steam used in distillation, storage time before re-running, water wash before caustic neutralisation, caustic wash, temperature of acid treatment and settling time. He gives a useful qualitative summary of his conclusions. Moehrle[2] has compared the utilisation of concentrated and 80 per cent. sulphuric acid for the refining of crude benzole whilst Scheider and Nettlenbusch[3] have proposed the use of 80–93 per cent. sulphuric acid at temperatures below 40° C. for the refining of this material.

Many recent papers and patents have been concerned with increasing the selectivity of the refining procedure either by using—

(*a*) A plurality of acid strengths, reagents or conditions, or

(*b*) by distillation into two or more fractions which are refined separately and subsequently recombined.

Under the first alternative may be mentioned the process of Retailliau[4] who after a preliminary soda wash treats the cracked distillate with a limited proportion of 30 per cent. sulphuric acid, separates, heats to 125–175° F. and treats with a higher proportion of acid 75–90 per cent. concentration. After settling, the treated oil is washed with sodium hydroxide 40° B. and rerun. By comparison with ordinary methods it is stated that the use of an elevated temperature and reduced acid concentration permits the

[1] *Refiner*, 1932, **11**, 455; *J. Inst. Petr. Techn.*, 1932, **18**, 396A.
[2] *Brenn. Chem.*, 1932, **13** (1), 6; *J. Inst. Petr. Techn.*, 1932, **18**, 96A.
[3] E.P. 380,495; *J. Inst. Petr. Techn.*, 1932, **18**, 463A.
[4] *J. Inst. Petr. Techn.*, 1932, **18**, 723.

retention of aromatics in the gasoline and a minimisation of the reduction in octane number.

Rowden[5] proposes the continuous treatment of gasoline with an excess of sulphuric acid, the resultant acid sludge being used for the continuous treatment of raw spirit until all the free acid has been used up, whilst Morrell[6] suggests a two-stage treatment using first orthophosphoric and then sulphuric acid. A method of treating pressure distillate using C.O.V. in two stages has been protected by Lewis.[7]

Acid and vapour-phase methods of refining cracked gasoline have been compared by Bespolov and Dunnenko[8] using a fraction of cracked gasoline (B range 175–200° C.) from Baku crude. A combination of acid and vapour-phase treatments is recommended. Somewhat more uncommon perhaps are the further methods of Morrell[9] and Schonberg.[10] According to the former a solution of sulphur dioxide in sulphuric acid at less than 32° F. under pressure may be used as a refining agent for cracked distillate, whilst the latter for the treatment of lubricating oil proposes the use of separate streams of sulphuric acid 66° B. or higher, a high pressure fluid rich in SO_2 and the lubricating oil, the three being forced into a mixing zone where pressure is rapidly reduced.

Finally with regard to the actual application of the acid there may be noticed the method of Melamid[11] for the acid treatment of lubricating oil using a powder reagent, consisting of 100 pts. of kieselguhr and 50 pts. C.O.V., which has been dried at 110° C. and the related procedure of Moreton[12] and others, who employ a mixture of sulphuric acid, silica and gypsum.

The second alternative previously mentioned for increasing the selectivity of refining processes is by sub-division, usually by distillation, into fractions before treatment in order that the refining process may be adapted more closely to or advantage taken of the peculiarities of each, the refined fractions being recombined to yield a marketable product. Thus Ferris and Henderson[13] claim the distillation of gasoline into fractions with the subsequent blending of those fractions of high anti-knock value. Wagner[14] refines vapour-phase cracked spirit by distillation into three fractions, the heaviest of which is refined with C.O.V., the second

[5] U.S.P. 1,845,723; *J. Inst. Petr. Techn.*, 1932, **18**, 165A.
[6] U.S.P. 1,853,920; *J. Inst. Petr. Techn.*, 1932, **18**, 258A.
[7] U.S.P. 1,876,702; *J. Inst. Petr. Techn.*, 1932, **18**, 430A.
[8] *Azerbaid Neft Choz*, 1931, **5**, 70–74.
[9] U.S.P. 1,853,921; *J. Inst. Petr. Techn.*, 1932, **18**, 258A.
[10] U.S.P. 1,831,265; *J. Inst. Petr. Techn.*, 1932, **18**, 54A.
[11] U.S.P. 1,847,778; *J. Inst. Petr. Techn.*, 1932, **18**, 216A.
[12] U.S.P. 1,828,429; *J. Inst. Petr. Techn.*, 1932, **18**, 16A.
[13] U.S.P. 1,868,102; *J. Inst. Petr. Techn.*, 1932, **18**, 382A.
[14] U.S.P. 1,873,728; *J. Inst. Petr. Techn.*, 1932, **18**, 383A.

with less concentrated acid whilst the third and lightest is subjected to polymerisation at elevated temperatures. The fractionation of cracked gasoline is also claimed by Seguy[15] and by Morrell[16], the latter fractionating the gasoline into two cuts, the lighter of which is alkali washed and the heavier cut is acid washed and neutralised. After refining and desulphurisation the fractions are recombined.

With reference to the exploitation of fractionation beyond the present accepted normal function of producing the maximum yield of white oils and pressable wax distillate, the communications of Fenske, Quiggle and Tongberg[17] particularly with regard to fractionation and knock rating, are of interest. In one fractionation, straight-run Pennsylvania crude was separated into fractions of alternate high and low knock rating, the variation being due to changes in the concentrations of the hydrocarbon classes present. It is suggested that the 20 per cent. or so of paraffins present are largely responsible for the knock and it is shown that these hydrocarbons can be so concentrated as to permit of their removal.

A similar trend is shown by Espach and Rue[18] in their communication on "Influence of Fractionation in Distribution of Sulphur and Gasoline" the general conclusion being that by proper fractionation into appropriate cuts before treatment a diminution of the chemical treatment that would otherwise be necessary, is possible.

Reverting to the consideration of the use of sulphuric acid, considerable attention has been paid to the finishing of acid treated oils.

The use of centrifugal separators for acid sludge removal has gained further notice by the contributions of Trival[19] and Backlund.[20] The former describes the application of centrifugal sludge separation to 10,000 brls. per day of 180° C. E.P. distillate. The distillate is subsequently clay treated and doctor sweetened. Using 8 lb. 66° B. acid per brl. P.D., contact time 3 min., centrifuging and 8 lb./clay per brl. P.D., the loss is assessed at ½ per cent. Backlund has described the application of the De Laval centrifuge both to dewaxing and to acid treatment. For the latter proportioned quantities of oil and acid are continuously fed into a mechanical mixer at a rate corresponding to the capacity of the separator. The intimate mixture of oil and acid passes into a reaction vessel where it remains a variable time depending on the oil under treatment and is then centrifuged. The process is

[15] U.S.P. 1,884,887; *J. Inst. Petr. Techn.*, 1932, **18**, 464A.
[16] U.S.P. 1,827,537; *J. Inst. Petr. Techn.*, 1932, **18**, 52A.
[17] *Ind. Eng. Chem.*, 1932, **24**, 542; *J. Inst. Petr. Techn.*, 1932, **18**, 253A.
[18] U.S. Bur. of Mines Tech. Paper 505, 1931; *J. Inst. Petr. Techn.*, 1932, **18**, 49A.
[19] *Refiner*, 1932, **11**, 312; *J. Inst. Petr. Techn.*, 1932, **18**, 273A.
[20] *J. Inst. Petr. Techn.*, 1933, **19**, 1.

applicable to pressure distillate, kerosine and lubricating oil. In the latter case it is suggested that the process is destined to effect a revolutionary change in refining costs.

Whilst it will be generally acknowledged that efficient mixing and subsequent efficient separation will effect economy in treating materials together with at least equivalence of product, some doubt still exists as to the balance between economies effected and a postulated increased depreciation due to corrosion of costly equipment.

The special difficulty associated with the refining of cracked distillates, *viz.*, the formation of oil soluble and neutral sulphates leading to acid formation on rerunning, etc., has been countered by the process of Gew. Matt. Stinnes[21] for the refining of motor spirit by treatment with dil. H_2SO_4 at less than 40° C. followed by alkali neutralisation and finally treatment with hot alkali. Troniseck,[22] after treatment in the liquid phase with sulphuric acid and soda lye, scrubs the vapours with alkali solution at a sufficiently high temperature to prevent condensation of the vapour. Moser[23] hydrolyses dialkyl sulphates using 20 per cent. or stronger caustic soda in the presence of emulsifying agents such as Turkey red oil, an interesting development. Emulsification for the promotion and control of reaction is common in the manufacture of synthetic plastics, but not frequently applied to petroleum refining.

Developments have also been proposed in the clay finishing of acid treated oils by the deposition of alkali or similar compound on the treating earth, Moreton[24] proposing the use of a material consisting of powdered non-absorbent silica coated with NaOH, and Cannon[25] a mixture of dry sodium carbonate and diatomaceous earth. The use of an earth previously activated by means of alkali, for example caustic soda or sodium silicate, is claimed by Pollock.[26]

The use of brucite or of magnesium hydroxide ex calcined magnesite has been described by Gardner and Higgins.[27] This material may be used for the neutralisation of acid-treated oils, phenol and sulphonated hydrogen removal and the conversion of mercaptides to disulphides. Dry granular hydroxide is used in treating cylinders. The reagent bed is regenerated *in situ* by boiling water, followed by dilute soda and water washes and drying.

As regards the use of other chemical refining agents, the majority

[21] E.P. 371,572 ; *J. Inst. Petr. Techn.*, 1932, **18**, 257A.
[22] E.P. 364,778 ; *J. Inst. Petr. Techn.*, 1932, **18**, 98A.
[23] *Petr. Z.*, 1932, **28**, 4.
[24] U.S.P. 1,861,711 ; *J. Inst. Petr. Techn.*, 1932, **18**, 346A.
[25] U.S.P. 1,881,044 ; *J. Inst. Petr. Techn.*, 1932, **18**, 466A.
[26] U.S.P. 1,847,442 ; *J. Inst. Petr. Techn.*, 1932, **18**, 216A.
[27] *Ind. Eng. Chem.*, 1932 **24**, 1141 ; *J. Inst. Petr. Techn.*, 1932, **18**, 439A.

of communications refer to gasoline and more particularly cracked gasoline.

The projected use of orthophosphoric acid for pre-treatment has already been noted, but the use of phosphorus pentoxide proposed by Malischer[28] is of interest both by reason of the reagent and the method of application. The pentoxide is mixed with asphalt by fusion and agitation. The mixture may be used for liquid-phase treatment by addition to the still containing cracked distillate or for vapour phase by passing the vapours through the asphalt oxide mixture suspended in heavy oil and maintained at a temperature of 200–250° C. The refining action is stated to take but a few minutes and the treated gasoline to be colourless, although it may require freeing from H_2S.

The use of an alkali metal has been proposed by several workers. Carlisle and Harris[29] specify the treatment of distillate with an alkali metal suspended in a liquid hydrocarbon, and Fields[30] claims for the treatment of distillate in the liquid phase and in the cold. Faught,[31] discussing the desulphurisation of gasoline, states that sodium at 350–400° F. completely removes S compounds yielding Na_2S, M.P. 750° F. as reaction product. This is difficult to handle being extremely hard. The gasoline obtained is free from gum and sulphur and does not require further treatment. On the semiplant scale it was found that the gasoline carries over sodium in fine suspension which settles only after long standing. A constant danger of explosion exists due to the reactivity of the metal with water and Faught concludes that a commercial application has yet to be devised. Refining with an alkali metal has been extended by Cross[32] to the countercurrent treatment of lubricating oil with a liquid alkali metal and to the vapour-phase refining of straight run or cracked gasoline using sodium or other alkali or alkaline earth metal.

Physical refining may be divided into five sections :—

(1) Heat and hydrogenation processes.
(2) Extension of distillation as a refining auxiliary, already discussed.
(3) Vapour-phase refining.
(4) Solvent processes.
(5) Dewaxing.

1. *Heat and Hydrogenation Processes.*—" Hydrogenation " in

[28] *Petr. Z.*, 27.4.32, **28** (17), 7 ; *J. Inst. Petr. Techn.*, 1932, **18**, 210A.
[29] U.S.P. 1,862,003 ; *J. Inst. Petr. Techn.*, 1932, **18**, 341A.
[30] U.S.P. 1,864,719 ; *J. Inst. Petr. Techn.*, 1932, **18**, 341A.
[31] *Refiner*, 1932, **11**, 272 ; *J. Inst. Petr. Techn.*, 1932, **18**, 219A.
[32] U.S.P. 1.865,235 ; *J. Inst. Petr. Techn.*, 1932, **18**, 346A.

many of its applications has a pronounced refining action. It may be regarded as an outlier of heat refining processes. Allocated a special section in this series of reviews, it is excluded from all but passing reference in this discussion.

Payne and Lowry[33] have studied the composition of highly cracked gasoline before and after heat treatment. Vapour-phase cracked gasoline was heated to 300° C. for 6 hrs. under 68 atm. pressure and then fractionally distilled. The fractions were compared with corresponding fractions from the original cracked gasoline. The major findings were: (1) Percentage of unsaturates was decreased by the treatment in all the fractions isolated; (2) percentage of naphthenes in the whole distillate up to 201·5° C. was increased; (3) increase of material B.P. 201·5° C. from 15·79 to 20·54 per cent.

Hugel and Kohn[34] have also investigated the influence of temperature and high pressure using pure unsaturated hydrocarbons.

Osterstrom has taken out a number of patents covering the heat treatment of cracked products. The method applied to Gyro distillate is described by Holland.[35] A mixture of Gyro distillate and clay at 200–500 lb. pressure is passed through a tube still to 600–650° F. As clay, very fine fullers earth, bentonite, Death Valley clay and others have been used. The mixture leaving the still passes through an orifice plate to reduce pressure, thence to vaporising drum and fractionating tower. The exothermic nature of the reaction is stated to render difficult the application of ordinary vapour-phase treatment.

Stevens and Gruse[36] have claimed the degumming of gasoline by heat treatment to 700–830° F. in the presence of hydrogen at 70 atms., followed by fractionation. Day[37] has covered the refining of naphtha by heating with aqueous alkali to 350–500° F. under pressure followed by vaporisation for separation.

Finally, Darlington[38] has proposed the heat treatment of lubricating oils, claiming stabilisation against oxidation by heating to 500–585° F. under pressure with air or oxygen in the presence of a colloidal adsorbent for, *e.g.*, bentonite.

3. *Vapour-Phase Refining.*—Although vapour-phase refining may be either chemical or physical according to the reagents employed it may be regarded conventionally as a physical process.

---

[33] *Ind. Eng. Chem.*, **24**, 432; *J. Inst. Petr. Techn.*, 1932, **18**, 163A.
[34] *Ann. des Comb. Liq.*, 1932, **7**, 15, 239; *J. Inst. Petr. Techn.*, 1932, **18**, 447A.
[35] *Refiner*, 1932, **11**, 26; *J. Inst. Petr. Techn.*, 1932, **18**, 86A.
[36] E.P. 370,671–2; *J. Inst. Petr. Techn.*, 1932, **18**, 257A.
[37] U. S.P. 1,867, 908; *J. Inst. Petr. Techn.*, 1932, **18**, 382A.
[38] U.S.P. 1,884,547; *J. Inst. Petr. Techn.*, 1932, **18**, 466A.

An article by Pfau and Barrere[39] describing the vapour-phase treatment of cracked distillate on a large scale, states that the use of two clay towers in series yields improved results and that the yield is dependent on the cracking stock used. Lachman[40] has brought forward evidence, obtained using a model treating plant, to demonstrate the applicability of the zinc chloride process, to the refining of cracked distillate secured from a range of cracked stocks representative both as to type of charging stock and cracking unit. Stating that the odour of cracked stocks is primarily due to mercaptans, the content of which is substantially reduced by zinc chloride treatment, a final sweetening with doctor solution is regarded as more economic than expansion of the chloride treatment. It is shown that zinc chloride treated distillates are practically as stable in tint after sweetening as before and Lachman suggests that high colour stability is associated with high gum stability, the latter being desirable since oxidation in storage may manifest itself in a loss of octane rating. Loss in octane rating in storage has never been observed in the case of zinc chloride refined gasoline. Over a range of sixteen stocks, the change of octane rating due to refining shows a maximum loss of two units in two cases only, whilst in eight instances an increment is recorded. Experience indicates that the concentration of the zinc chloride solution is of greater significance than the temperature of treatment. The efficacy of the treatment is not affected by the presence of fixed gases or by low concentrations of sulphuretted hydrogen. High concentrations of the latter, 5 per cent. or more, increase slightly the amount of zinc chloride consumed.

Kubulnek,[41] considering the Lachman process, advocates a caustic soda treatment followed by water, prior to zinc chloride contacting, in order to remove mercaptans, sulphuretted hydrogen and sulphur, so that the formation of hydrochloric acid and zinc sulphide, which are corrosive to plant, may be avoided. Lachman, however, in an earlier communication q.v.,[42] has considered this question of plant corrosion. Similar to the application of zinc chloride just mentioned is the use of other liquid reagents for vapour-phase treatment. Vapour-phase treatment with an aqueous solution of a salt or salts of copper[43] in 50–85 per cent. concentration at 300–400° F. and the use of an aqueous solution of metallic iodides or iodine salts[44] are claimed.

---

[39] *Petr. Eng.*, Oct., 1932, **3** (1), 18; *J. Inst. Petr. Techn.*, 1932, **18**, 20A.
[40] *Petroleum World* (Los Angeles), Sept., 1932, 38.
[41] *Neftyanoe Khozyaistvo*, 1932, **22**, 104.
[42] *Refiner*, 1931, **10** (11), 72; *Oil & Gas J.*, 1931, **30** (26), 30; *J. Inst. Petr. Techn.*, 1932, **18**, 6A.
[43] E.P. 359, 419.
[44] Oberle, U.S.P., 1,843,156; *J. Inst. Petr. Techn.*, 1932, **18**, 165A.

The Frasch process using copper oxide having enjoyed popularity in the treatment of S containing crudes, it is not surprising that the use of copper and copper compounds, either in solution as just mentioned or as a deposit on a carrier, has been extended to vapour-phase refining. Cross[45] suggests the use of a material containing a metallic compound, preferably copper having a high affinity for sulphur, whilst Graves[46] claims that gum forming bodies are removed from distillate by contact at raised temperatures with metallic copper, followed by adsorbent clay. The use of iron salts has also been suggested by Cross,[47] who specifies treatment with a running steam of a basic iron compound plus an adsorbent clay intimately mixed with a copper compound, and by Morrell[48] for the vapour-phase treatment of cracked spirit with SO_2 and an oxygen containing gas in the presence of ferric sulphate.

The use of sodium and the alkali metals in general have also been proposed as previously noted.

Endeavours have been made to extend the use of vapour-phase methods to the refining of lubricating oils as illustrated by the patents of Gray[49] and Apga.[50]

4. *Solvent Processes.*—There have been additions to the reagents proposed as selective solvents. Agitation with liquid phenol[51] at a temperature below that of complete miscibility, the selective solvent action of anhydrous phenol at 140–250° F.[52] and an extension thereof are the subjects of patents. Ferris[53] claims the use of aromatic acetates and organic thiocyanates and Hill[54] of furfuryl alcohol.

The most significant development in this sphere has been the further development of the nitrobenzene and Edeleanu processes, permitting of a more drastic refining whilst largely retaining selectivity. Ferris and Houghton,[55] in a paper presented at the Thirteenth Annual Meeting of the A.P.I., state that whilst sulphur dioxide is more selective, nitro-benzene is capable of producing the more paraffinic raffinate by reason of its greater solvent power. Nitrobenzene is shown to be capable of handling a wide range of lubricating stocks. The refined oil invariably has a lower viscosity

[45] U.S.P. 1,840,158 ; *J. Inst. Petr. Techn.*, 1932, **18**, 99A.
[46] U.S.P. 1,867,697 ; *J. Inst. Petr. Techn.*, 1932, **18**, 382A.
[47] U.S.P. 1,882,000 ; *J. Inst. Petr. Techn.*, 1932, **18**, 463A.
[48] U.S.P. 1,855, 486 ; *J. Inst. Petr. Techn.*, 1932, **18**, 258A.
[49] U.S.P. 1,839,388 ; *J. Inst. Petr. Techn.*, 1932, **18**, 90A.
[50] U.S.P. 1,841,271.
[51] Standard Oil Dev. Co., E.P. 362,600 ; *J. Inst. Petr. Techn.*, 1932, **18**, 89A.
[52] Stratford, U.S.P. 1,860,823 ; *J. Inst. Petr. Techn.*, 1932, **18**, 308A.
[53] U.S.P. 1,874,946–7 ; *J. Inst. Petr. Techn.*, 1932, **18**, 385A.
[54] U.S.P. 1,883,374 ; *J. Inst. Petr. Techn.*, 1932, **18**, 466A.
[55] *Refiner*, 1932, **11**, 560 ; *Oil & Gas J.*, 17.11.32, **31** (26), 65 ; *J. Inst. Petr. Techn.*, 1933, **19**, 61A.

than the charge, and increasing the nitrobenzene oil ratio to produce extremely paraffinic oils results in still lower viscosities as well as decreased yields. The yields of refined oil cited for a number of charging stocks vary from a minimum of 21 to a maximum of 80. Perhaps 50 per cent. might be taken as a typical figure, although this does not evaluate the viscosity loss which is additional to the volumetric.

The suggestion that sulphur dioxide is lacking in solvent power has been countered to some extent by the development of the Edeleanu process using a mixture of SO_2 and benzole[56] as the extraction medium. The type of oil under treatment, the desired quality of finished product and economic considerations determine the benzole/SO_2 ratio. Too high a proportion of benzole decreases the selectivity of the solvent and in general the proportion of benzole is less than 50 per cent. For examples cited, the percentage of raffinate varies from 48–92 per cent.

The potential drastic refining action which is a feature of both these processes is indicative of a trend towards the production of oils of the greatest possible stability. This additional stability is only achieved by the sacrifice of substantial proportions of the less saturated constituents, *i.e.*, compounds, say, of series C_nH_{2n-6} to C_nH_{2n-20}, and therefore at an increment in production costs. From time to time suggestions have been made that unsaturated compounds and their congeners are of marked lubricating value. In spite of these views, however, the refining tendency is definitely to remove a high proportion of the substances mentioned, and the latest developments briefly described above, coupled with the success of the hydrogenated and synthetic lubricants, indicate that high gravities and all that they imply are unlikely to prove acceptable features of high duty oils.

5. *Dewaxing.*—Solvent dewaxing using solvents other than benzine continues to attract attention. The use of methylene chloride has been investigated by Carlisle and Devine,[57] who report that this material has a high selective solubility at low temperatures, yielding oils of nearly the same pour as the chilling temperature. The wax may be separated by filtration or centrifuging. A somewhat similar process is proposed by the Edeleanu Ges.[58] whereby oils to be dewaxed are diluted with a halogen substituted hydrocarbon, gaseous at ordinary temperatures. The commercial application of centrifugal separation coupled with trichlorethylene dilution has been described by Backlund (*loc. cit.*).

[56] Kain, *Refiner*, 1932, **11**, 553; *J. Inst. Petr. Techn.*, 1933, **19**, 27A.
[57] *Ind. Eng. Chem.*, 1932, **24**, 384; *J. Inst. Petr. Techn.*, 1932, **18**, 168A.
[58] E.P. 373,538; *J. Inst. Petr. Techn.*, 1932, **18**, 308A.

Livingstone[59] has claimed for the separation of wax by the use of a mixed solvent, consisting of a good and poor solvent for waxes, so called differential solvents. In an example cited 80 parts of wax distillate were mixed with 36 parts of benzole (good wax solvent) and 84 parts of ethylene dichloride and the mixture cooled to $-20°$ F. The filtrate stripped of solvent had a cold test of $-20°$ F.

Other patents referring to the use of solvents are those of Lindgren and Malm,[60] Buch[61] and Voorhees.[62] Jones[63] claims to negative the existent difficulty of separating crystalline wax by centrifuge by the addition of amorphous wax. Two patents, each claiming the agglomeration of wax, are those of Funster[64] and Schott,[65] the former adding a coal tar high boiling compound and the latter a petroleum distillation residue of high gravity.

Poole,[66] in collaboration with Manglesdorf, has published Part III. of the account of his researches into the solubility of oils and waxes in organic solvents.

The following appear to be the more significant trends in chemical and physical refining :—

(1) The increase of selectivity of chemical refining either by division of a product into parts for refining or by gradation of the action of the refining agent used.
(2) The further development of distillation as a refining auxiliary both for facilitating (1) and for the accentuation of product qualities.
(3) The heat treatment of cracked gasoline.
(4) The drastic refining of lubricants associated with the new solvent processes.
(5) The continued endeavour to establish solvent dewaxing, using chlorinated solvents and the like.

---

[59] U.S.P. 1,848,636 ; *J. Inst. Petr. Techn.*, 1932, **18**, 216A.
[60] U.S.P. 1,847,488 ; *J. Inst. Petr. Techn.*, 1932, **18**, 216A.
[61] U.S.P. 1,848,054 ; *J. Inst. Petr. Techn.*, 1932, **18**, 216A.
[62] U.S.P. 1,862,874 ; *J. Inst. Petr. Techn.*, 1932, **18**, 346A.
[63] U.S.P. 1,881,643 ; *J. Inst. Petr. Techn.*, 1932, **18**, 466A.
[64] U.S.P. 1,857,370 ; *J. Inst. Petr. Techn.*, 1932, **18**, 309A.
[65] U.S.P. 1,857,404 ; *J. Inst. Petr. Techn.*, 1932, **18**, 309A.
[66] *Ind. Eng. Chem.*, 1932, **24**, 1215 ; *J. Inst. Petr. Techn.*, 1933, **19**, 16A.